PA⁻⁻NT COOPERATION TREAT`

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

BIRD, William
Bird Göen & Co.
Vilvoordsebaan 92
B-3020 Winksele
BELGIQUE

Date of mailing (day/month/year) 26 September 2000 (26.09.00)	
Applicant's or agent's file reference S1334-PCT	**IMPORTANT NOTIFICATION**
International application No. PCT/EP99/04085	**International filing date** (day/month/year) 28 June 1999 (28.06.99)

1. The following indications appeared on record concerning:

☐ the applicant ☐ the inventor ☒ the agent ☐ the common representative

Name and Address	State of Nationality	State of Residence
BIRD, William Bird Göen & Co. Termerestraat 1 B-3020 Winksele Belgium	Telephone No. 32 16 48 05 62	
	Facsimile No. 32 16 48 05 28	
	Teleprinter No.	

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person ☐ the name ☒ the address ☐ the nationality ☐ the residence

Name and Address	State of Nationality	State of Residence
BIRD, William Bird Göen & Co. Vilvoordsebaan 92 B-3020 Winksele Belgium	Telephone No. 32 16 48 05 62	
	Facsimile No. 32 16 48 05 28	
	Teleprinter No.	

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

☒ the receiving Office
☐ the International Searching Authority
☒ the International Preliminary Examining Authority
☐ the designated Offices concerned
☒ the elected Offices concerned
☐ other:

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer C. Cupello Telephone No.: (41-22) 338.83.38

P' 'ENT COOPERATION TREA'

From the INTERNATIONAL BUREAU

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NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 20 March 2000 (20.03.00)	
International application No. PCT/EP99/04085	**Applicant's or agent's file reference** S1334-PCT
International filing date (day/month/year) 28 June 1999 (28.06.99)	**Priority date** (day/month/year) 29 June 1998 (29.06.98)
Applicant CNOCKAERT, Dirk et al	

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:

12 January 2000 (12.01.00)

☐ in a notice effecting later election filed with the International Bureau on:

2. The election ☒ was ☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Aino Metcalfe Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

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INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference S1334PCT	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/EP 99/ 04085	International filing date *(day/month/year)* 28/06/1999	(Earliest) Priority Date *(day/month/year)* 29/06/1998
Applicant SINVACO N.V. et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.
      [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).
   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :
      [ ] contained in the international application in written form.
      [ ] filed together with the international application in computer readable form.
      [ ] furnished subsequently to this Authority in written form.
      [ ] furnished subsequently to this Authority in computer readble form.
      [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
      [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).
3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**
   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**
   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1
   [ ] as suggested by the applicant.
   [X] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.
   [ ] None of the figures.

Form PCT/ISA/210 (first sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International Application No
PC[redacted]P 99/04085

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F16L21/06 F16L23/08 F16L37/08 C23C14/34 H01J37/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F16L C23C H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 480 193 A (ECHOLS JOSEPH A ET AL) 2 January 1996 (1996-01-02) cited in the application	1,6
Y	column 2, line 46 -column 3, line 40; figures 1-3	3
Y	US 5 467 612 A (VENETUCCI JIM M) 21 November 1995 (1995-11-21) cited in the application abstract; figures 4,27,30	3
A	US 5 591 314 A (MORGAN STEVEN V ET AL) 7 January 1997 (1997-01-07) cited in the application abstract; figure 2	1,7,8

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 October 1999	02/11/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Donnelly, C

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International Application No
PC[illegible]P 99/04085

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 94 16118 A (BOC GROUP INC) 21 July 1994 (1994-07-21) page 12, line 3 -page 12, line 14; figures 4,5 page 14, line 12 -page 15, line 32 ---	1,4,8,10
A	US 5 527 439 A (SIECK PETER A ET AL) 18 June 1996 (1996-06-18) column 6, line 43 -column 6, line 48; figure 2 ---	10,12
A	WO 92 02659 A (VIRATEC THIN FILMS INC) 20 February 1992 (1992-02-20) page 10, line 4 -page 11, line 17; figure 1 -----	10,11

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INTERNATIONAL SEARCH REPORT

Inform[illegible]n patent family members

International Application No
PC[illegible]P 99/04085

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5480193 A	02-01-1996	NONE	
US 5467612 A	21-11-1995	CA 2144930 A	30-10-1995
US 5591314 A	07-01-1997	AU 7729896 A	15-05-1997
		CA 2235864 A	01-05-1997
		EP 0873431 A	28-10-1998
		WO 9715697 A	01-05-1997
WO 9416118 A	21-07-1994	AU 678213 B	22-05-1997
		AU 6161694 A	15-08-1994
		CA 2153795 A	21-07-1994
		CN 1094759 A	09-11-1994
		CZ 9501810 A	13-12-1995
		EP 0681616 A	15-11-1995
		JP 8506855 T	23-07-1996
		US 5464518 A	07-11-1995
US 5527439 A	18-06-1996	AU 690388 B	23-04-1998
		AU 4071395 A	01-08-1996
		CA 2165884 A	24-07-1996
		CN 1134469 A	30-10-1996
		EP 0724025 A	31-07-1996
		JP 8239758 A	17-09-1996
		SG 33637 A	18-10-1996
		ZA 9600172 A	15-07-1996
WO 9202659 A	20-02-1992	CA 2089149 A	11-02-1992
		EP 0543931 A	02-06-1993
		JP 6503855 T	28-04-1994
		US 5470452 A	28-11-1995
		US 5725746 A	10-03-1998

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REC'D 22 SEP 2000
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PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference S1334PCT	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/EP99/04085	International filing date *(day/month/year)* 28/06/1999	Priority date *(day/month/year)* 29/06/1998
International Patent Classification (IPC) or national classification and IPC F16L21/06		
Applicant SINVACO N.V. et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 2 sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☐ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☐ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   VI ☐ Certain documents cited
   VII ☐ Certain defects in the international application
   VIII ☐ Certain observations on the international application

Date of submission of the demand 12/01/2000	Date of completion of this report 20.09.2000
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Donnelly, C Telephone No. +49 89 2399 2763

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP99/04085

I. Basis of the r port

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

Description, pages:

1-10	as originally filed			

Claims, No.:

1-13	as received on	06/07/2000	with letter of	06/07/2000

Drawings, sheets:

1/6-6/6	as originally filed			

2. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

V. R asoned stat ment und r Articl 35(2) with regard to novelty, inv ntiv step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-13
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-13
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-13
	No:	Claims	

2. Citations and explanations

see separate sheet

Re Item V

Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Patent document US-A-5480193 (D1) describes a vacuum tight coupling for end portions of two tubular sections, the size of the inner space of a first end portion (10) being smaller than that of a second end portion (15), the second end portion (15) having a flange extremity (15a) axially slidable over the first end portion (10) to abut the flange extremity (15a) against a peripheral outer abutment ring (10a) on said first end portion (10), the coupling comprising at least one sealing ring (12,13) between said end portions in their overlapping contact area and further comprising a clamping ring (25) with a substantially cylindrical outer surface and being composed of two substantially equal halves (25a,25b), each clamp half having a semi-circular cross-section with an inwardly oriented recess (25c), said recess (25c) enclosing said flange extremity (15a) and said abutment ring (10a), the two ring halves being fixed to each other at their extremities by means of fixing means comprising in at least one place bolting means (18,20,22), the axis of which is perpendicular to the longitudinal axis of the coupled tubular sections and substantially tangential to the clamping ring periphery.

2. The apparatus according to claim 1 differs therefrom in the sense that the recess is adapted to positively and solidly axially clamp the abutment ring against the flange extremity (whereas in the device according to D1 an annular spring (14) is present which would diminish any solidity of the joint).

3. The positive and axially solid clamping of the coupling according to claim 1 means that it is particularly suitable for use in rotating applications where a vacuum tight joint must be maintained over a period of time.

4. The subject-matter of claim 1 therefore meets the requirements of Articles 33(2) and (3) PCT.

5. Claims 2-13 describe further embodiments of or with the device according to claim 1 and thus also meet the requirements of Articles 33(2) and (3) PCT.

CLAIMS

1. A vacuum tight coupling for end portions (1,2) of two tubular s ctions, the size of the inner space of a first end portion (1) being smaller than that of a second end portion (2), the second end portion having a flange extremity (11) axially slidable over the first end portion to abut the flange extremity 11 against a peripheral outer abutment ring (10) on said first end portion, the coupling comprising at least one sealing ring (4,5) between said end portions in their overlapping contact area and further comprising a clamping ring (3) with a substantially cylindrical outer surface and being composed of two substantially equal halves (12,13), each clamp half having a semi-circular or U-shaped cross section with an inwardly oriented recess (6), said recess enclosing said flange extremity (11) and said abutment ring (10) and being adapted to positively, solidly and axially clamp the abutment ring (10) against the flange extremity (11), the two ring halves being fixed to each other at their extremities (15,16) by means of fixing means comprising in at least one place bolting means (9), the axis (14) of which is perpendicular to the longitudinal axis of the coupled tubular sections and substantially tangential to the clamping ring periphery.

2. A coupling according to claim 1 wherein said flange extremity (11) is a separate ring.

3. A coupling according to claim 1 or 2, wherein the ring halves, besides said bolting means (9) for fixing their extremities (15,16) in one place comprise pivoting means (17) for fixing them in their opposite extremities (21,22).

4. A coupling according to any previous claim, wherein the first end portion comprises a tubular insert (20) is coupled between ~~said first~~ a tubular section and the second end portion, and wherein the insert end (23) facing the ~~first end portion (1)~~ tubular section is a ring which can slide axially over said ~~first end portion~~ tubular section whereas th opposite ins rt end (24) is a ring over which said second end portion (2) can slid .

< The coupling according to any of the claims 10 to 12, wherein the arcing element touches the surface of the sputtering target. >

5. A coupling according to any previous claim, wher in the length of th overlap portion between th first and second tub portions (1, 2) is 50% or less, preferably 30% or less, more preferably 20% or less of the inner diameter of the first portion.

6. A coupling according to any previous claim, wherein the length of the overlap portion between the first and second end portions (1, 2) is 5% or more of the inner diameter of the first portion.

7. A coupling according to any previous claim, wherein the coupling is an high vacuum or ultra-high vacuum coupling.

8. A coupling for a cylindrical sputtering target comprising the coupling according to any of claims 1 to 7.

9. The coupling for a cylindrical sputtering target according to claim 8, wherein the fixing means of the clamping ring (3) is located on the side of the coupling remote from the sputtering target.

10. The coupling for a cylindrical sputtering target according to claim 8 or 9, further comprising an anti-arcing element (32, 36) attached to a surface of the clamping ring (3) on the same side as the sputtering target for preventing arcing.

11. The coupling for a cylindrical sputtering target according to any of claims 8 to 10, wherein the anti-arcing element is conductive or insulating.

12. The coupling for a cylindrical sputtering target according to any of claims 8 to 11, wherein a at least one groove (38, 39) is provided between the anti-arcing element and the clamping ring (3).

13. < >

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : F16L 21 /06, 23 /08, 37 /08, C23C 14 /34, H01J 37 /34 — A1

(11) International Publication Number: WO 00/00766

(43) International Publication Date: 6 January 2000 (06.01.00)

(21) International Application Number: PCT/EP99/04085

(22) International Filing Date: 28 June 1999 (28.06.99)

(30) Priority Data:
98202183.4 29 June 1998 (29.06.98) EP

(71) Applicant *(for all designated States except US)*: SINVACO N.V. [BE/BE]; Karreweg 20, B-9870 Zulte (BE).

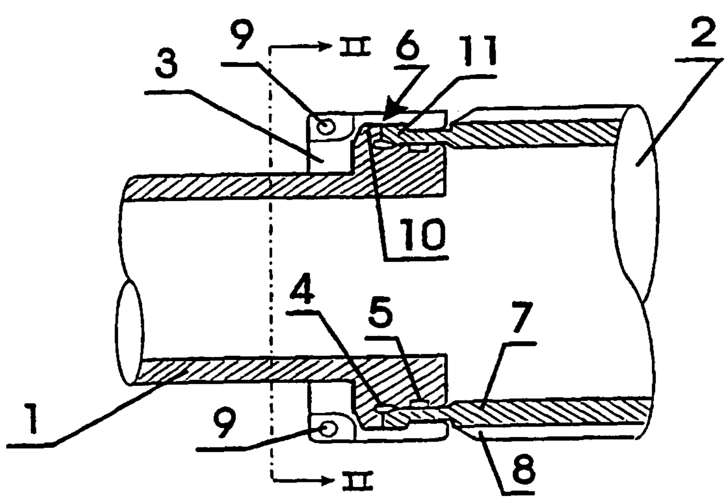
(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: CNOCKAERT, Dirk [BE/BE]; Izegemstraat 80, B-9800 Deinze (BE). DE BOSSCHER, Wilmert [BE/BE]; Noordhoutstraat 22, B-9031 Drongen (BE). LOOTENS, Erwin [BE/BE]; Mariakerksesteenweg 269, B-9031 Drongen (BE). VERHEYEN, Pascal [BE/BE]; Provinciebaan 102, B-9890 Gavere (BE).

(74) Agents: BIRD, William et al.; Bird Göen & Co., Termerestraat 1, B-3020 Winksele (BE).

(81) Designated States: CA, CN, JP, KR, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: VACUUM TIGHT COUPLING FOR TUBE SECTIONS



(57) Abstract

The invention relates to a vacuum tight coupling for the end portions (1, 2) of two tubular sections, the size of the inner space of a first end portion (1) being smaller than that of the second end portion (2). The second end portion, with its flange extremity (11) can axially slide over the first end portion against an abutment ring (10) on said first end portion. The coupling includes at least one sealing ring (4, 5) between said end portions and a clamping ring (3) with a substantially cylindrical outer surface. The ring (3) is composed of two substantially equal halves (12, 13) with each a U-shaped cross section with an inwardly oriented recess (6), said recess enclosing said flange and said abutment against each other. The two ring halves are fixed to each other at their extremities (15, 16) and the fixing means comprises in at least one place bolting means (9).

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Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

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EE	Estonia	LR	Liberia	SG	Singapore		

VACUUM TIGHT COUPLING FOR TUBE SECTIONS

The invention relates to a vacuum tight coupling for the end portions of two tubular sections. In particular it relates to the coupling of heavy tube sections which have to rotate around their longitudinal tube axis such as, for example, rotatable targets in vacuum sputtering reactors, in particular magnetrons.

Background of the invention

Vacuum or at least fluid tight couplings for tube ends are known from the patent publications DE 3328137; US 4,900,063; US 5,591,314; WO 85/04940 and EP 0726 417. Most of these coupling devices include clamping rings that, due to the nature of their fixing means, do not have a substantially cylindrical outer surface. This prevents tube rotation within a small opening surrounding -i.e. radially facing - the clamping rings. In addition, when joined, the transverse tube extremities essentially abut with their end faces against each other with sealing means positioned in between them in this transverse abutment area. When one tube end has to carry the other heavy tube, e.g. in cantilever mode and optionally has to set it in rotation, e.g. at a considerable speed, then the structure of these known abutment-type couplings is subjected to virtually insupportable stresses and loads.

US 5,480,193 describes a push-on fitting including a split clamp. An inner tube end is provided with two "O" ring seals and an outer tube end is pushed over the seals. Each half of the axial clamp includes a semi-annular surface positioned to encircle that portion of the push-on fitting lying over the seals. Elastic inserts are placed in the clamp which clamp down onto the outer tube. Due to the use of elastic components there is some possibility of relative movement between the inner and outer tube.

US 5,647,612 describes a push-on tube fitting which is clamped by a hinged clamp. In the closed position the two halves of the clamp co-operate to form a recess corresponding to that of the fitted part of the couplings, thereby axially restraining the couplings but not clamping them together. The clamp is held closed by a releasable locking mechanism.

Object and summary of the invention

It is an object of the invention to avoid the disadvantages of known couplings and to provide a reliable vacuum tight coupling for relatively heavy tube sections. It is also an object to design such a coupling which permits rotation at relatively high speeds when needed. It is a further object to produce a coupling which can easily be assembled and disassembled and which is readily usable e.g. as a spindle/target-coupling for a rotatable sputtering target. The coupling is designed for multiple disassembly and reassembly. After fixing the coupling, the spindle may be attached to its supporting unit, e.g. an end block which is provided with the connections for driving and cooling the inner space of the target tube.

In the vacuum tight coupling for the end portions of two tubular sections according to the present invention the inner diameter of the first end portion is chosen to be smaller than that of the second end portion. This second end portion carries a radially outwardly extending flange extremity and this portion can be slid axially over the first end portion to abut against a peripheral outer abutment ring on said first end portion. At least one sealing ring is provided between said end portions in their overlapping cylindrical contact area. The coupling comprises further a clamping ring with a substantially cylindrical outer surface. This ring is composed of two substantially equal halves with each a U-shaped cross section with an inwardly oriented recess, said recess enclosing said flange portion of the second end portion and said abutment ring of the first end portion. Tightening of the clamp results in longitudinal (axial) positive clamping of the abutment ring to the flange. The clamp operates directly on the flange and ring. Preferably, the load bearing surfaces of the clamp, flange extremity and abutment ring are made of metal, e.g. steel. The fixing means for the ring halves comprise in at least one place bolting means, the axis of which is perpendicular to the longitudinal axis of the coupled tubular sections and substantially tangential to the clamping ring periphery.

To provide for a robust coupling, said overlapping cylindrical contact

area, where one tube end enters the other, should exceed a minimum surface in relation to the inner diameter "d" of the first end portion. For example, the minimum overlap may be 5% of the inner diameter of the first end portion. In this manner the entering tube end will offer a proper mechanical support for the surrounding tube end during any conditions of operation. To allow ease of coupling in confined spaces the amount of overlap should preferably be limited in length. For example, it is preferred if the length of overlap between the first and second end portions is 50% or less of the inner diameter "d" of first end portion. more preferably 30% or less and most preferably 20% or less. The overlap may be 10%. This amount of overlap is sufficient to provide both enough space for sealing rings and also mechanical stability.

To prevent arcing is it preferable to attach an anti-arcing element to the surface of the clamping ring. The anti-arcing element may be a ring. The anti-arcing element may be made of an insulating or a conductive material.

The invention will now be described with reference to the attached drawings. Further details and advantages will be clarified, in particular in relation to certain preferred embodiments for couplings for spindles to rotatable targets.

Brief description of the drawings

Fig. 1 is a longitudinal cross sectional view of a coupling according to an embodiment of the present invention.

Fig. 2 is a transverse cross section of Fig. 1 showing clamping ring halves.

Fig. 3 is a longitudinal cross sectional view of an alternative embodiment wherein, i.a. the flange extremity on the second end portion is a separate ring.

Fig. 4 shows a transverse cross section of the clamp of Fig. 3.

Fig. 5 shows in longitudinal cross section an alternative embodiment of the fixing arrangement for the two halves of the clamping ring.

Fig. 6 shows a transverse cross-section of the clamp of Fig. 5.

Fig. 7 relates to the insertion of a tubular section between first and

second end portions of the two couplings.

Fig. 8 is an exploded schematic view of a coupling according to a further embodiment of the present invention.

Fig. 9 is a longitudinal cross-sectional detail of the coupling of Fig. 8.

Detailed description of certain embodiments

The present invention will be described with reference to certain embodiments and to certain drawings but the present invention is not limited thereto but only by the claims. The coupling in accordance with the present invention is particularly suitable as a vacuum coupling. The couplings in accordance with the present invention are not only suitable for levels of vacuum in the range 0.5 to 0.01 bar but are also suitable for high vacuum levels such as 10^{-3} or lower, in particular 10^{-5} or lower, for example 10^{-6} to 10^{-9} bar. Couplings in accordance with the present invention may be ultra-high vacuum couplings. Ultra-high vacuum in accordance with this invention is 10^{-10} bar or lower, e.g. 10^{-11} down to 10^{-15} bar.

An embodiment of a vacuum tight coupling in accordance with the present invention is shown schematically in Fig. 1. Generally, the structural materials of the coupling may be made of a metal, e.g. steel, or any other suitable high strength material. The coupling has end portions 1, 2 of two tubular sections. The first end portion 1 may have a smaller inner diameter than that of end portion 2. When applying the invention to a spindle/target-coupling, the first end portion 1 is part of, or fits into or onto the spindle and the second end portion 2 is part of the target tube or fits into or onto the target tube. The target tube may have an inner support tube 7 onto which the cylindrical layer 8 of target material is fixed. The size of the inner space of the first end portion 1 is smaller than that of the second end portion 2. The second end portion 2 carries a flange extremity 11 which can be slid axially over the first end portion 1 to come to rest abutted against a peripheral outer abutment ring 10 on said first end portion. The contact between the abutm nt ring 10 and the flange 11 will be called the abutment area.

The coupling includes at least one sealing ring 4, 5 between said end

portions in their overlapping contact area. Sealing ring 4, 5 may be an O-ring seal. An O-ring 5 is preferably arranged in a circumferential groove on the outside of the end portion of the spindle. An O-ring 4 is preferably located near the abutment area with the end portion of the target tube. Although one O-ring could in principle assure a vacuum tight sealing, two O-rings warrant a maximal vacuum integrity under the most extreme conditions of operation. Both O-rings 4 and 5 are mounted on the spindle during assembly. This arrangement provides an automatic and uniform pressure on the seal which minimises the risk of damaging them or the sealing surfaces during assembly, revision, cleaning and target exchange. The couplings in accordance with the present invention are designed for repetitive assembly and disassembly while still maintaining their mechanical properties, e.g. suitable for vacuum or ultra-high vacuum conditions. Rubber O-ring seals (e.g. Viton™ rubber O-rings) are suitable for high vacuum use, i.e. down to about 10^{-9} bar. Due to outgassing from the rubber such rings are not preferred for ultra-high vacuum use. Toroidal flexible metal seals supplied under the trade name Helicoflex™ (supplier Le Carbone-Lorraine, France) may be used instead of rubber O-rings for ultra-high vacuums, e.g. 10^{-11} to 10^{-15} bar.

The coupling comprises further a clamping ring 3 with a substantially cylindrical outer surface. Substantially cylindrical means that the envelope of the outer circumference of the ring with its fixing means 9 does not show parts which extend radially outside said circumference to a significant extent. As a result, cylindrical shields may be placed quite closely over the clamp without touching it, even during relative rotation between the clamp and the cylindrical shield. Clamping ring 3 is preferably made from a high strength material such as a metal, e.g. steel. The clamping ring 3 is composed of two substantially equal halves 12, 13, each having a semi-circular or U-shaped cross section with an inwardly oriented recess 6. Upon closing the ring 3, said recess 6 encloses the flange 11 and said abutment ring 10. Tightening of the clamp halves 12, 13 forces thereby the transversal end faces of the abutment ring 10 and the flange 11 tightly against each other by means of the conically machined edges (25 in Figs. 3, 9). The clamp 3 provides not only longitudinal

or axial restraint of the two end portions 1, 2 but also actively and positively clamps ring 10 to flange 11. Clamp 3 preferably has at least one bevelled inner edge 25 which co-operates during clamping with a chamfered edge 28 on one of the ring 10 or flange 11 (as shown in Fig. 3 the chamfered edge 28 is on the ring 10). The angle of the chamfer/bevel should be such as to provide a strong axial pressure on the respective ring 10 or flange 11. On the other one of the ring 10 or flange 11 there may be no chamfered/bevelled edges (as shown in Fig. 3) or these edges may also be provided with co-operating chamfers 29, 30 (Fig. 9). By clamping the flange 11 to the abutment ring 10 in a solid manner, relative movement between ring 10 and flange 11 is prevented, independent of whether this movement is axial with respect to end portions 1, 2 or rotational about a rotation axis parallel to the axis of end portions 1, 2 or rotational about an axis perpendicular to the axis of end portions 1, 2. This means that during rotation of the coupling, any circumferential out of balance forces do not result in repetitive small rotational or linear movements which could damage the seals 4, 5 or produce periodic movements which could cause periodic variations in the processing, e.g. when sputtering. The two ring halves 12, 13 are fixed to each other at their extremities 15, 16 by a fixing means, e.g. bolts 9.

The fixing means comprises in at least one place bolting means 9, the longitudinal axis 14 of which is perpendicular to the longitudinal axis of the coupled tubular sections and substantially tangential to the clamping ring periphery. This securing of the clamp halves 12, 13 together is shown here with only two bolts 9 which are screwed in threaded holes in the clamp end face 16. They can be reached and seen very easily at any rotational position of the clamp 3. This guarantees a fast and user friendly interface for mounting and removing a cylindrical tube, in particular a rotatable target. In this embodiment, as shown in Fig. 2, both bolts are fastened from the same side. This coupling system does not have to be turned through 180° about its longitudinal axis to couple and clamp the tube ends. When used for target-to-spindle couplings, the screw holes for the bolts are provided at the spindle side (towards end portion 1) to prevent or reduce the sputtering of material

onto the bolts. Clamping ring 3 preferably have a solid section into which the holes for the bolts 9 are provided. The clamping ring 3 also have a recess for receiving the outer circumferential edges of the flange 11 and ring 10. This recess is preferably placed axially asymmetrically with respect to the bolts 9, i.e. to one side of the recess resulting in a smaller outer diameter for the clamp 3.

In a further embodiment shown schematically in Figs. 3 and 4 the bolts 9 are oriented in opposite directions to each other. In this manner each ring halve 12, 13 is identical and thus replaceable by the opposite one 13, 12. Fig. 3 shows the use of a separate flange ring 11 at the end of the overlapping tube section 2. This feature offers the advantage that the supporting tube 7 for the target does not need to be produced each time with a flange at its end. Separate flange rings 11 can be interposed that properly fit with the design ad hoc of tube end 2 and the co-operating clamping ring 3. The flange ring 11 is fixed to the tube end 2, e.g. by welding.

In Figs. 5 and 6 an alternative design of the clamping ring 3 is shown. The two ring halves 12 and 13 are pivotably linked to each other in one contact area of their extremities 21 and 22 by means of pivot pins 17 suitably mounted in a pivoting block 26. The two halves can be pivoted in an open position 19. The other extremities 15 and 16 are then suitably fixed to each other by a bolt 9 in an internally screw threaded bore 18.

In certain vacuum chambers of sputtering reactors it is useful to provide for different sputtering widths. This corresponds to different lengths of the rotatable targets to be used. The active width of the sputtering area may thus be substantially shorter than the distance between the two opposite spindles which carry the target tubes. In this manner it is advantageous to provide at least one tubular insert section 20, as shown in Fig. 7, between spindle 1 and target tube 2. The transverse end 23 of the insert tube 20, that faces the first end portion 1 (spindl-) is then again a ring which can slide axially over said first end portion. Likewise the opposite end 24 of the insert tube 20 is a ring over which said second end portion 2 can slide. This end is again provided with a suitable circumferential groove 27 for a sealing ring.

A further clamping device 3 in accordance with an embodiment of the present invention is shown schematically in Figs. 8 and 9 and can be provided with additional rings 31 and/or 32 which may be used to prevent arcing in a sputtering magnetron. One of the tube ends (2) is part of a rotating cylindrical target and can be advantageously used in a reactive sputtering process. Use of the clamping device 3 in accordance with this embodiment prevents arcing when used in a vacuum deposition process. The numbering of the various parts in Figs. 8 and 9 corresponds with those of the previous embodiments, except In previous embodiments the material to be sputtered 8 was applied onto a backing tube 7. In this embodiment the material to be deposited may be in the form of a massive tube 2 provided with an integral ring 37 fixed to the end thereof and having the appropriate clamping flange 11. Thus, in accordance with this embodiment the second end portion is 37. However, the present embodiment is not limited thereto but may include the flange fixing methods described with reference to Figs. 1 and 3.

The clamping device 3 is used as a means for mounting a cylindrical rotating target represented by 2 to a spindle represented by 1. Clamping device 3 may include two clamping semi-circular halves 12, 13 which may be fastened together with any of the fixing means described with reference to Figs. 1 to 7. The outer circumference of clamp 3 is substantially cylindrical as has been described with respect to all the previous embodiments. Clamp 3 provides positive axial clamping of the abutting flanges 10, 11. For this purpose, the clamping halves 12, 13 are provided with at least one bevelled surface 25, 29 which co-operates with at least one chamfered surface 28, 30 on the ring 10 and/or the flange 11 to force the ring 10 and the flange 11 together and to clamp their machined abutting surfaces positively together.

A cross-sectional view of the extended clamp in accordance with this embodiment is shown below in Fig. 9. Fig. 8 shows an exploded view. Additional rings 31 and 32 are provided which may be in two pieces, while reference numbers 33 and 34 represent retaining rings (made from a suitable material such as spring steel) for securing split rings 31 and 32 close to the clamp halves 12 and 13. Rings 33, 34 may be single pieces. Retention may

be done by inserting a number of fixing pins 35 (e.g. four) through the clamp halves 12 and 13. Rings 31 and 32 provide a functional contribution during the reactive sputtering process. Retaining rings 33 and 34, together with pins 35 are intended to enable attachment of rings 31 and 32 to the clamp halves 12 and 13 which have been described in detail above. Ring 31 may be made of insulating material and is intended to isolate ring 32 electrically from the clamp halves 12, 13. Ring 31 is not essential when ring 32 is insulating. During a sputtering process, clamp halves 12, 13 are brought to the same potential as the target 2. Ring 32 may be made of insulating material as well. The axially directed annular lip 36 on the inner diameter of ring 32 extends over the target 2 and may have a rectangular shape in cross-section although the present invention is not limited thereto. For instance, a saw tooth-like shape, of which the edge touches the target 2 exactly at the edge of the plasma race-track induced above the target 2 in a sputtering magnetron could also be used. The present invention includes within its scope other forms of the lip 36 which extend over the target surface appropriately designed for different process conditions.

In an alternative embodiment, the ring 32 may be made from a conductive material and slightly spaced from the target surface. This ring 32 may be brought to a desired potential, grounded or be electrically floating. In this case, the presence of insulating ring 31 is advantageous to insulate the conductive ring 32 from the clamp halves 12, 13 which are at a potential. Additional, in this configuration, pins 35 should be designed to prevent electrical contact of the clamp halves 12, 13 with ring 32. For example, this can be achieved by using insulating pins or by putting an insulating sleeve over these pins. The lip 36 on 32, extending over the target 2, is preferably equally spaced over the target surface. The lip end, shown in Fig. 9 as having a rectangular cross-section, could have a round, saw tooth or alternative cross-section. This metallic shield may be beneficial in reducing arcing during sputtering processes. This metallic shield is not connected electrically and will assume a floating potential after plasma ignition.

Preferably, both rings 31 and 32 have a geometry at their outer

circumference which provides a groove 39 between clamp halves 12, 13 and ring 31 when they are fixed together and a labyrinth groove 38 between rings 31 and 32. During a sputtering process, not only the substrate is covered with the required film, but all other bodies and walls in the vacuum chamber are coated as well. This means that eventually ring 31 and 32 will be covered with a sputtered film. If the sputtered coating is conductive, an electrical short may be formed from the clamp halves 12, 13 over the insulating ring 31 to ring 32. If ring 32 is conductive and this ring is to be maintained at a potential different from the clamp potential, it is important that no conductive path between both is formed. By providing a complex groove 38 between rings 31 and 32 and a groove 39 between clamp halves 12, 13 and ring 3, the chance of having a conductive path is reduced considerably.

The skilled person will appreciate that the present invention also includes within its scope the independent invention of a coupling for a cylindrical sputtering target comprising an anti-arcing element attached to the side of the coupling facing the sputtering target. The coupling may be used to couple a cylindrical target to a spindle. The spindle may be driven to rotate the coupling and the target. The envelope of the outer surface of the coupling may be substantially circular so that the coupling may be placed within a close fitting tubular shield. Two end portions of two tubular sections may be coupled with this coupling, the size of the inner space of a first end portion being smaller than that of a second end portion, the second end portion having a flange extremity axially slidable over the first end portion to abut the flange extremity against a peripheral outer abutment ring on said first end portion, the coupling comprising at least one sealing ring between said end portions in their overlapping contact area and further comprising a clamping ring with a substantially cylindrical outer surface and being composed of two substantially equal halves, each clamp half having a semi-circular or U-shaped cross section with an inwardly oriented recess, said r cess enclosing said flange extremity and said abutment ring.

CLAIMS

1. A vacuum tight coupling for end portions (1,2) of two tubular sections, the size of the inner space of a first end portion (1) being smaller than that of a second end portion (2), the second end portion having a flange extremity (11) axially slidable over the first end portion to abut the flange extremity 11 against a peripheral outer abutment ring (10) on said first end portion, the coupling comprising at least one sealing ring (4,5) between said end portions in their overlapping contact area and further comprising a clamping ring (3) with a substantially cylindrical outer surface and being composed of two substantially equal halves (12,13), each clamp half having a semi-circular or U-shaped cross section with an inwardly oriented recess (6), said recess enclosing said flange extremity (11) and said abutment ring (10) and being adapted to positively and axially clamp the abutment ring (10) against the flange extremity (11), the two ring halves being fixed to each other at their extremities (15,16) by means of fixing means comprising in at least one place bolting means (9), the axis (14) of which is perpendicular to the longitudinal axis of the coupled tubular sections and substantially tangential to the clamping ring periphery.

2. A coupling according to claim 1 wherein said flange extremity (11) is a separate ring.

3. A coupling according to claim 1 or 2, wherein the ring halves, besides said bolting means (9) for fixing their extremities (15,16) in one place comprise pivoting means (17) for fixing them in their opposite extremities (21,22).

4. A coupling according to any previous claim, wherein a tubular insert (20) is coupled between said first and second end portion, and wherein the insert end (23) facing the first end portion (1) is a ring which can slide axially over said first end portion whereas the opposite insert end (24) is a ring over which said second end portion (2) can slide.

5. A coupling according to any previous claim, wherein the length of the overlap portion between the first and second tube portions (1, 2) is 50% or less, preferably 30% or less, more preferably 20% or less of the inner diameter of the first portion.

6. A coupling according to any previous claim, wherein the length of the overlap portion between the first and second end portions (1, 2) is 5% or more of the inner diameter of the first portion.

7. A coupling according to any previous claim, wherein the coupling is an high vacuum or ultra-high vacuum coupling.

8. A coupling for a cylindrical sputtering target comprising the coupling according to any of claims 1 to 7.

9. The coupling for a cylindrical sputtering target according to claim 8, wherein the fixing means of the clamping ring (3) is located on the side of the coupling remote from the sputtering target.

10. The coupling for a cylindrical sputtering target according to claim 8 or 9, further comprising an anti-arcing element (32, 36) attached to the clamping ring (3) on the same side as the sputtering target for preventing arcing.

11. The coupling for a cylindrical sputtering target according to any of claims 8 to 10, wherein the anti-arcing element is conductive or insulating.

12. The coupling for a cylindrical sputtering target according to any of claims 8 to 11, wherein a at least one groove (38, 39) is provided between the anti-arcing element and the clamping ring (3).

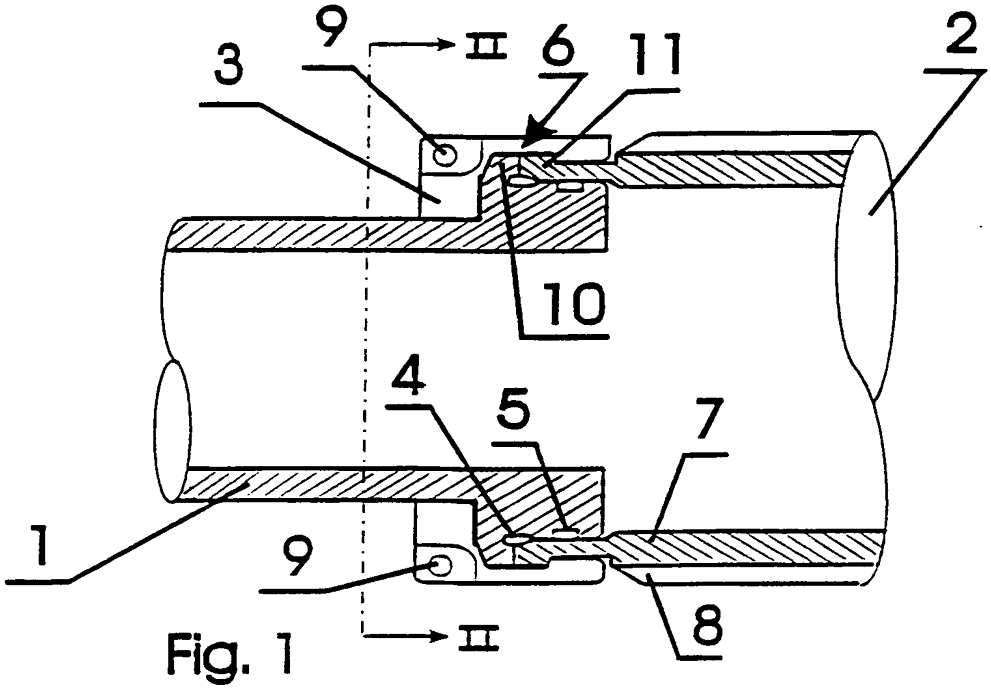

Fig. 1

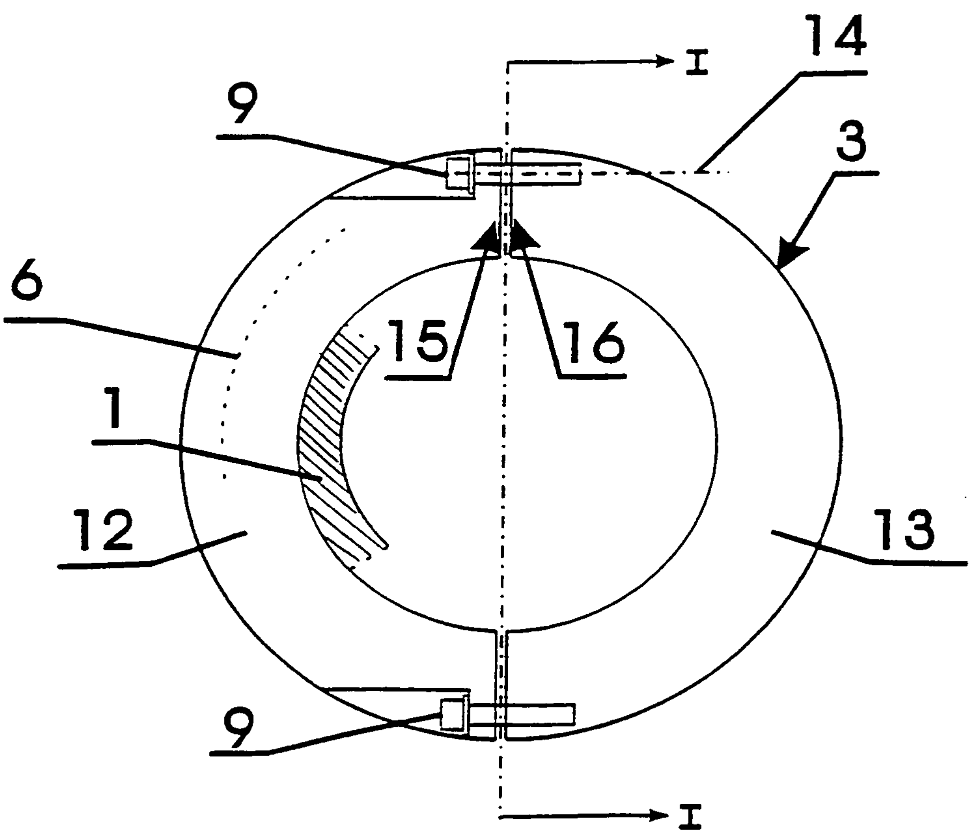

Fig. 2

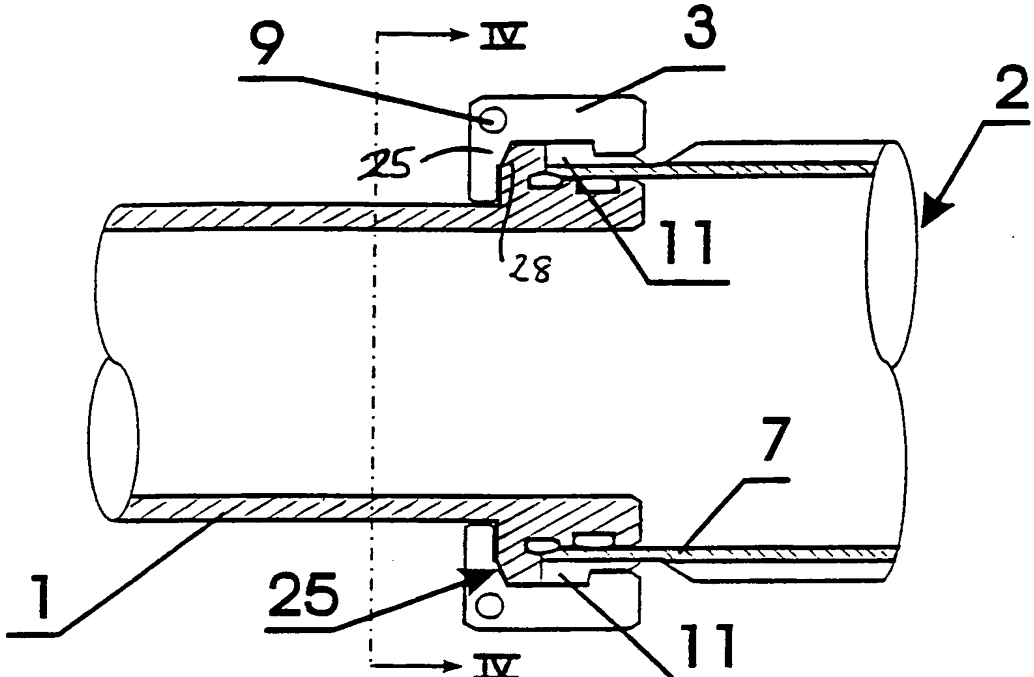

Fig. 3

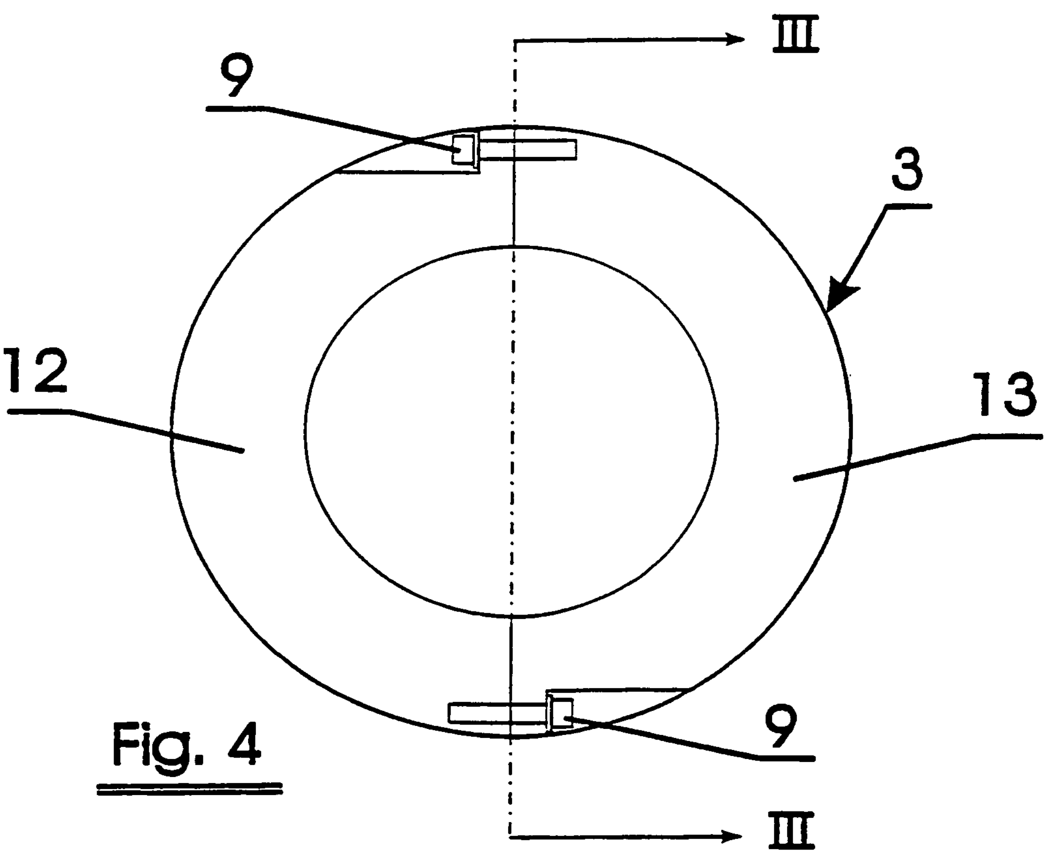

Fig. 4

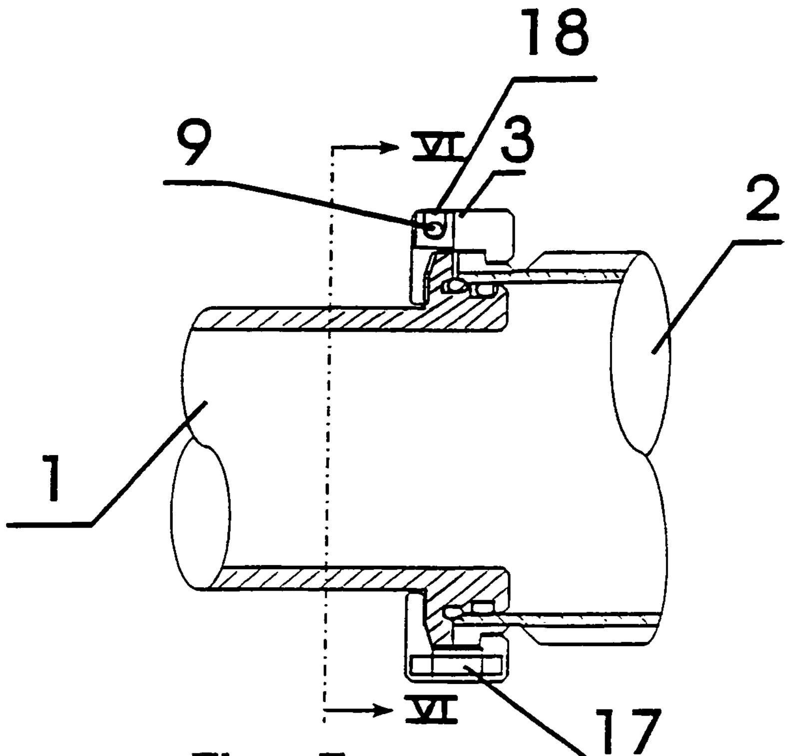

Fig. 5

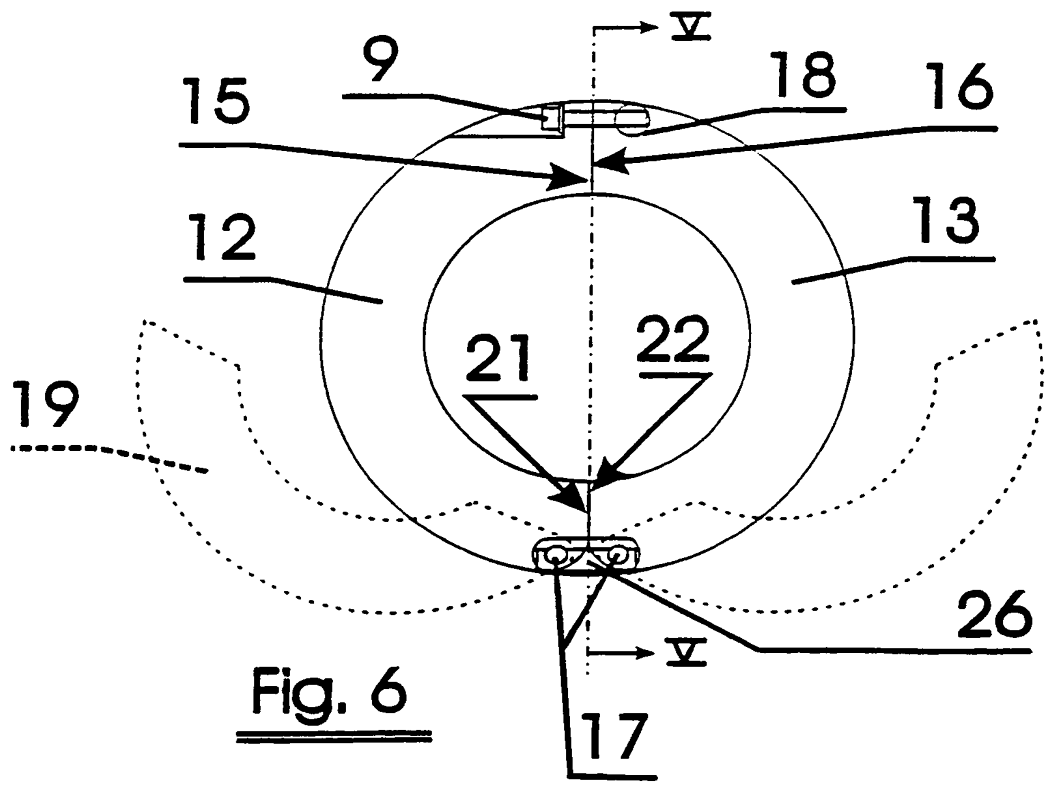

Fig. 6

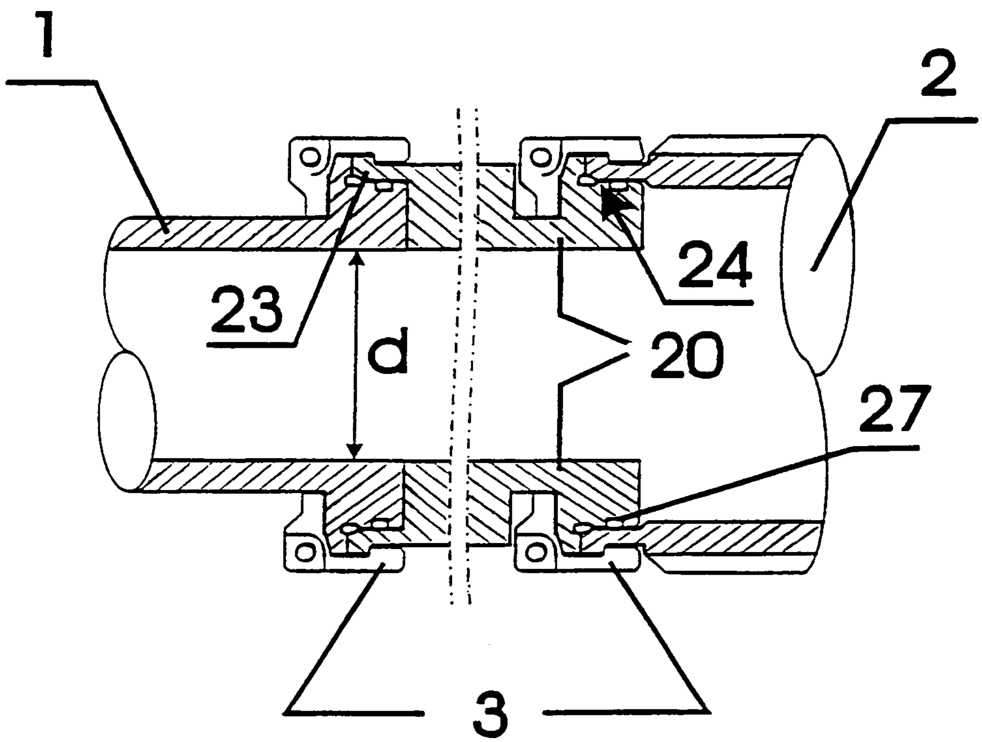

Fig. 7

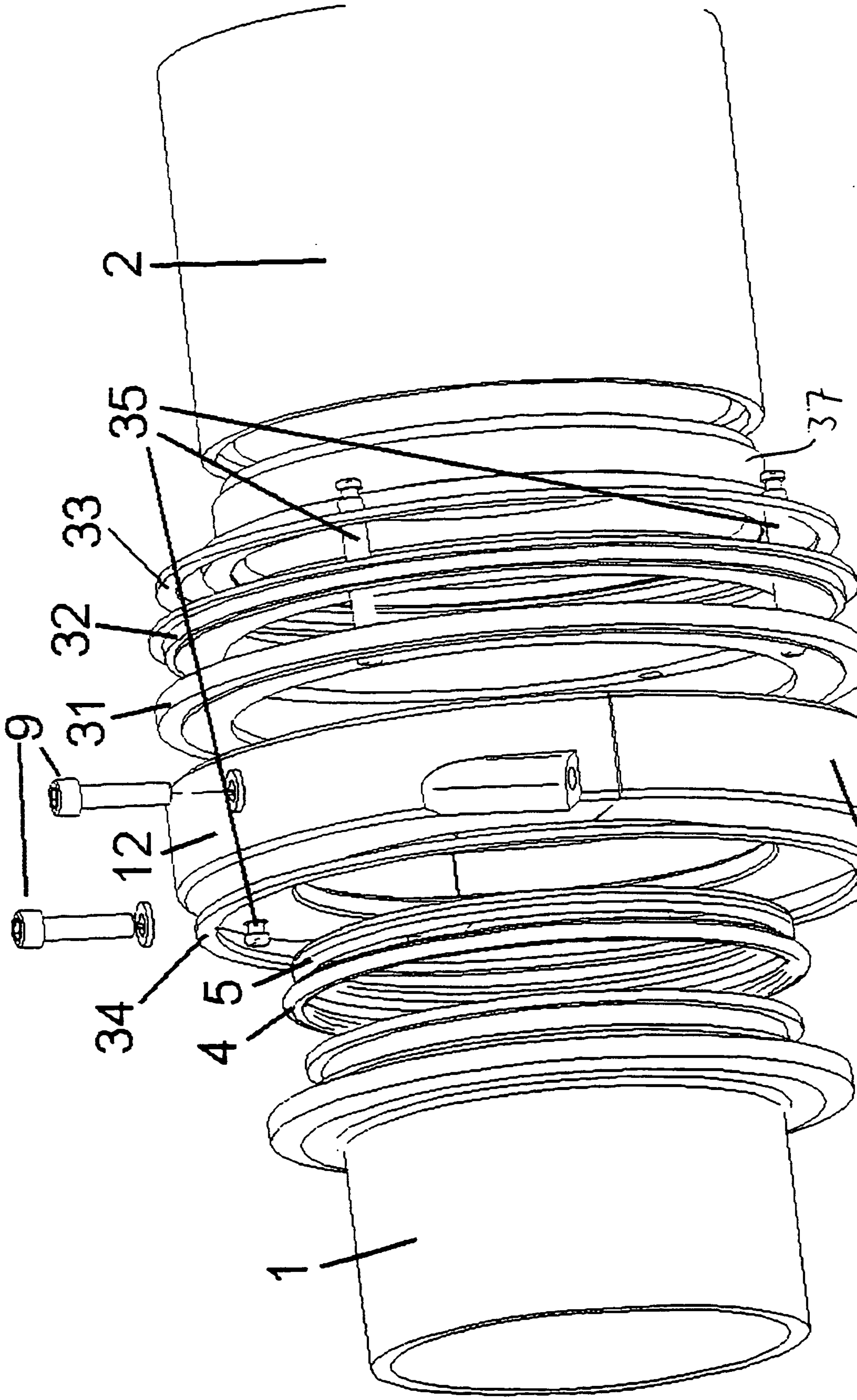

Fig. 8

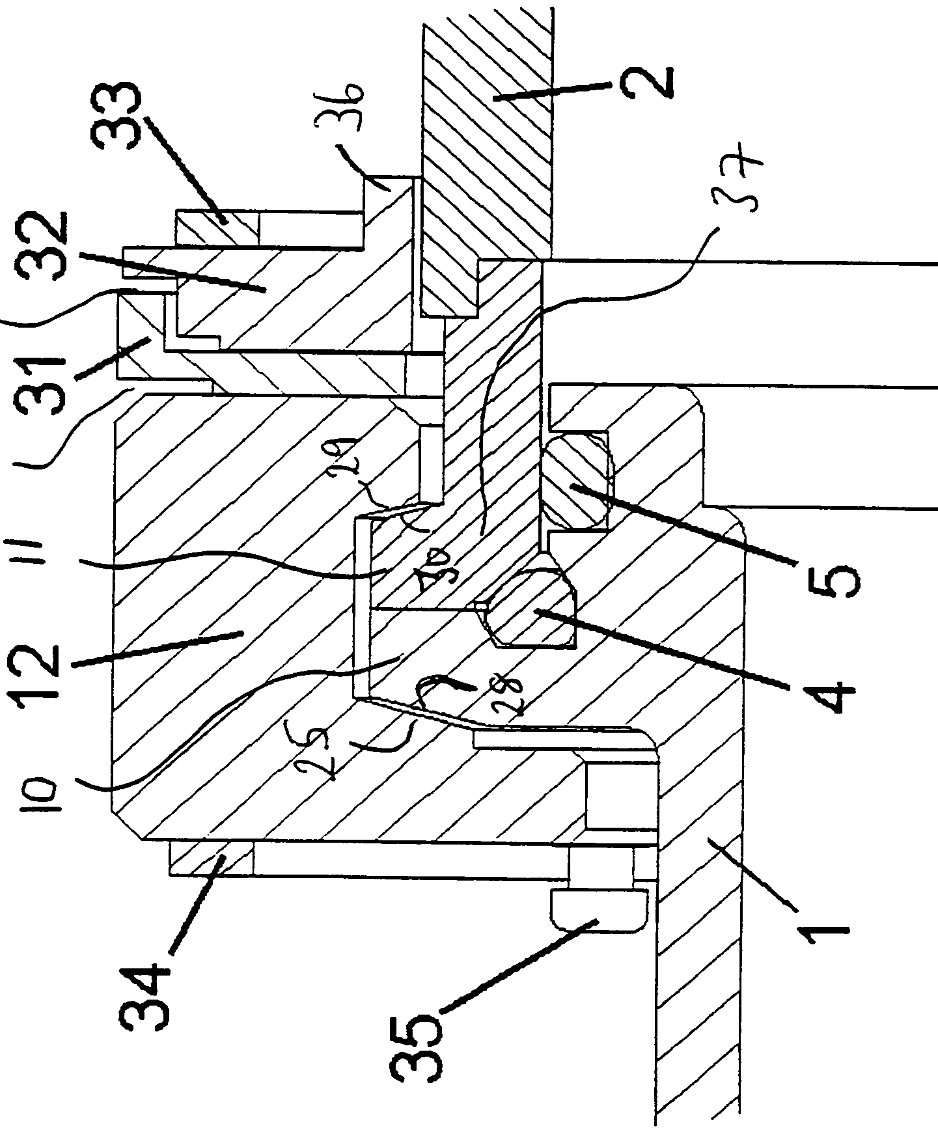

Fig. 9

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 99/04085

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F16L21/06 F16L23/08 F16L37/08 C23C14/34 H01J37/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F16L C23C H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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[X] Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search	Date of mailing of the international search report
22 October 1999	02/11/1999

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 99/04085

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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2

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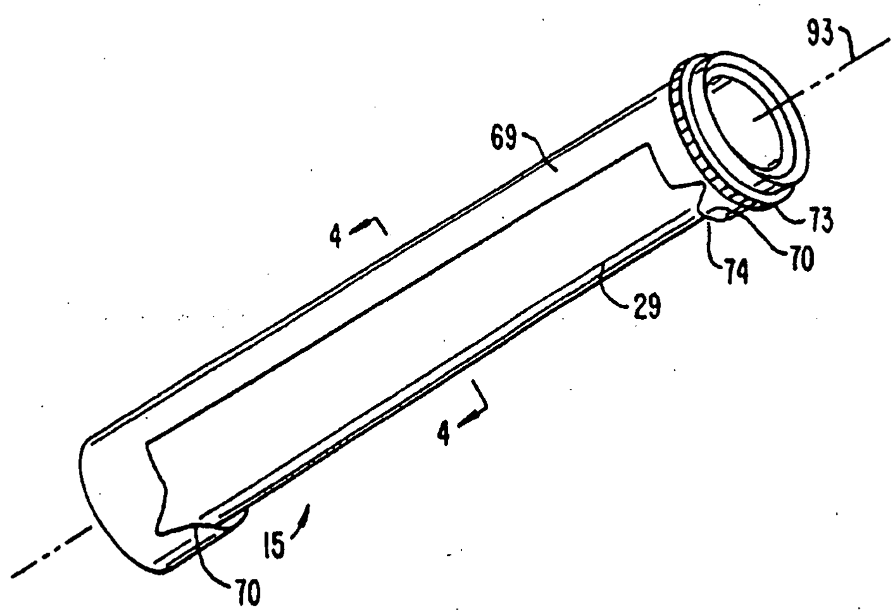
Published
With international search report.

(54) Title: CYLINDRICAL MAGNETRON SHIELD STRUCTURE



(57) Abstract

A rotating cylindrical sputtering target surface (29) as part of a magnetron has cylindrical shields (70) adjacent each end of the target (29) that are shaped at their respectiv inner edges (70) to maximize etching and to prevent condensation and subsequent arcing that undesirably occurs when certain materials, particularly dielectrics, are being sputtered. If two or more rotating targets (29) are employed in a single magnetron system, each is similarly shielded. In an alternative form, the targ t (29) is provided with a single cylindrical shield (69) that is cut away for a significant porti n f the distance around the cylinder to provide an opening through which a sputtering region of the target is accessible, while maintaining shielding f the target end regions. This alternative single shield (69) is similarly shaped at porti ns of its inner edges adjacent to th opening to maximize etching and to prevent undesired condensation and subsequent arcing. The preferred shield structure (69) is rotatable in order to allow the position of the sputtering activity to be selected.

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CYLINDRICAL MAGNETRON SHIELD STRUCTURE

Background of the Invention

This invention relates generally to magnetrons of a type using rotating cylindrical sputtering targets, and, more specifically, to structures and techniques for minimizing arcing in such magnetrons.

Cylindrical magnetrons are becoming widely used for depositing films on substrates. An example is the deposition of a stack of dielectric and metal layers on a surface of a glass substrate for the purpose of filtering out a portion of solar energy from passing through the glass. Such a substrate is positioned within a vacuum chamber containing at least one, and usually two, rotating cylindrical targets containing sputtering material on an outer surface thereof. Both inert and reactive gases are generally introduced into the chamber. A voltage applied to the sputtering target, with respect to either the vacuum chamber enclosure or a separate anode, creates a plasma that is localized along a sputtering zone of the target by stationary magnets positioned within the target. Material is sputtered off the target surface and onto the substrate by bombarding the target with electrons and ions of the plasma as it passes through the stationary sputtering zone.

The magnets are usually of a permanent magnet type, arranged along a line within the rotating cylindrical target and held against rotation with the target. The sputtering zone is created by the magnets along sub-

stantially the entire length of the cylindrical sputtering target and extends only a small circumferential (radial) distance around it. Traditionally, the magnets are arranged so that the sputtering zone exists at the bottom of the cylindrical target, facing a substrate being coated directly beneath.

Although deposition of the film is desired to take place only on the substrate, it is also deposited on other surfaces within the reactive chamber. This can create a problem in many situations, especially when certain dielectrics are being deposited as the film. For example, if the target surface is silicon or aluminum and the reactive gas is oxygen, silicon dioxide is deposited on the target surface, surfaces of target supporting structures, and the like, as well as on the substrate that is intended to be coated. After a certain build-up of dielectric material on internal vacuum chamber surfaces has occurred over time, arcing to those surfaces can begin. Arcing is undesirable since it generates particles that contaminate the film being deposited on the substrate, and overloads the power supply that creates the plasma through an electrical connection with the sputtering target surface and the vacuum chamber walls or some other anode.

An advantage of a rotating cylindrical sputtering target is that such a film deposited on the target is subjected to being sputtered away as the target surface passes through the sputtering zone, thus counteracting the undesirable film build-up. Despite this self-cleaning characteristic, however, undesirable arcing still occurs in rotary magnetrons under certain circumstances.

Recently, a cylindrical magnetron shield structure has been developed to minimize this undesirable arcing that occurs in rotary cylindrical magnetrons. S e Kirs, Milan R., et al., "Cylindrical Magnetron

Shield Structure," U.S. Patent No. 5,108,574. As shown in Kirs et al., the deposition of dielectric film can be minimized by dark space shielding, which prevents plasma formation in the dark space and thereby reduces film deposition and subsequent arcing.

Although the shield structure of Kirs et al. greatly enhances the self-cleaning characteristic of rotary cylindrical magnetrons, some deposition of condensate has been found to occur at the far ends of the target cylinder. Unlike the deposition of dielectric films that concerned Kirs et al., this deposition of condensate from the vapor present in the system occurs regardless of the existence of plasma. Thus, the problem of condensate deposition is not fully resolved by the use of dark space shielding.

Because even slight deposition of dielectric or insulating materials can lead to undesirable arcing, it is a principal object of the present invention to provide a mechanism and technique for further minimizing such deposition and related arcing.

Summary of the Invention

This and additional objects are accomplished by the present invention, wherein, briefly and generally, a shaped cylindrical shield structure is provided around and spaced apart from at least a portion of the sputtering target outside of said sputtering zone. By careful examination of the shape of the magnetic field zone and the distribution of the condensate at the ends of the tube, the shape of the cylindrical shield structure is designed to conform to the contours of the magnetic field zone, thereby maximizing sputter etching of the tube ends while minimizing deposition of condensate. In a preferred form, the shield structure consists of separate cylindrical end shields positioned at opposite ends of the target structure and shaped at

their respective inner edges adjacent to the magnetic field zone to conform to the outer contours of the "race-track" pattern of the magnetic field zone. The shield structure may also consist of a unified shield wherein these shaped cylindrical end shields are connected at the portions their respective inner edges lying outside the magnetic field zone by a cylindrically shaped structure, leaving a window opening in the shield structure adjacent to the magnetic field zone so that the target surface is bombarded by electrons and ions of the plasma as it is rotated through the sputtering zone. The cylindrical shield structure does not rotate with the cylindrical target. In systems that provide for the sputtering zone to be circumferentially positionable around the target by rotation of its magnets, the cylindrical shield structure is also made rotatable so that its window may follow the sputtering zone to its new position.

Such a shield structure has been found to be beneficial in three primary respects. First, it has been found that the self-cleaning attribute of a rotating sputtering target generally does not extend to the far ends of the target cylinder since the sputtering zone controlled by the magnets within the cylinder does not extend completely to its ends. An abrupt termination of the permanent magnets within the target cylinder creates some discontinuities in the sputtering zone at the ends of the cylinder, and thus in the character of the plasma itself. Since the self-cleaning attribute of a rotating target does not fully extend to the ends of the target cylinder, the shield structure of the present invention extends completely around the sputtering cylinder at its ends and, further, may be extended to cover portions of rotating target support structures adjacent to its ends which are particularly susceptible

to undesirable film build-up because of their proximity to the sputtering surface and plasma.

Additionally, it has been found that much like planar magnetrons, rotary cylindrical magnetrons etch the sputtering surface in a "race-track" pattern, while causing a buildup of arc-causing condensate film at the ends of the target cylinder in a pattern that conforms to the shape of the "race-track." Since this undesirable condensate film conforms to the "race-track" shape of the magnetic field zone, the shield structure of the present invention is similarly shaped to conform to the contours of the magnetic field zone, thereby shielding those areas at the ends of the target cylinder that would otherwise be exposed to condensate film build-up and subsequent arcing.

A third beneficial aspect of the shield structure comes from covering a central portion of the length of the sputtering target cylinder, despite the self-cleaning attribute of a rotating magnetron mentioned above. It has been found that there are circumstances where an undesired dielectric or other film deposited on portions of the target outside of the sputtering zone are not completely removed when those surface portions again pass through the sputtering zone. Further, there are circumstances where it has been found desirable to be able to cover a portion of the cylindrical target surface during co-sputtering; that is, in a situation where two rotating cylindrical target structures are adjacent one another and material from at least one of them is being sputtered onto the surface of another before being resputtered onto a substrate. Such co-sputtering techniques are described in U.S. Patent Application Serial No. 07/549,392, filed July 6, 1990, now abandoned, which is incorporated herein by this reference. It is the ability to cover a portion of the

target during such co-sputtering that is provided by the present invention.

Additional objects, features and advantages of the present invention will become apparent from the following description of a preferred embodiment thereof, which description should be taken in conjunction with the accompanying drawings.

Brief Description of the Drawings

Figure 1 schematically illustrates a dual cylindrical sputtering target magnetron that utilizes the improvement of the present invention;

Figure 2 shows in isometric view a portion of one of the target assemblies of Figure 1, including the improvement of the present invention;

Figure 3 shows in isometric view a portion of one of the target assemblies of Figure 1, including the improvement of the present invention;

Figure 4 is a cross-section of a target assembly taken at Section 4-4 of Figure 2;

Figure 5 is a partial section view of a preferred support assembly for a rotating target assembly of the types illustrated in Figures 1-5; and

Figure 6 shows in isometric view a "race-track" pattern of etching and a conforming pattern of condensation at the end portions of a cylindrical sputtering target assembly of Figure 1 that are used in designing the improvement of the present invention.

Description of a Preferred Embodiment

Referring initially to Figure 1, an entire magnetron system utilizing the present invention is generally described before the details of the invention's preferred implementation are explained. A box 11, shown in dotted outline, indicates metallic walls of a vacuum chamber in which the sputtering occurs. Within

that chamber are two rotatable cylindrical target structures 13 and 15 which are held by the frame 11 in a manner to be rotatable about their longitudinal axes. The target structures 13 and 15 are generally held with their axes parallel to one another, but that is not a requirement. Further, although two target structures are illustrated in Figure 1, many applications need only employ one such target, and other applications can benefit by having more than two. However, the use of two target structures 13 and 15 is common.

The magnetron of Figure 1 is shown to have a substrate 17 held by a support structure 19. The support structure 19 may be rollers to allow the substrate 17 to be passed through the vacuum chamber in a continuous process. A vacuum is drawn within the vacuum chamber by an appropriate pumping system 21. One or more gases are provided by a supply 23 to the vacuum chamber by some convenient delivery system, such as a perforated tube 25 positioned across the vacuum chamber. The particular gases utilized depend primarily upon the film desired to be deposited on the substrate 17.

Cylindrical pieces 27 and 29 of sputtering material provided as part of the target structures 13 and 15, respectively, are generally made of the same material but can be of different materials, depending upon the nature of the film to be deposited on the substrate 17. An electric motor source 31, positioned outside the vacuum chamber, rotates the target assemblies by rotating, through a toothed belt 33, pulleys 35 and 37 which are attached to respective spindles 39 and 41. The sputtering materials 27 and 29 are attached to the respective spindles 39 and 41 in order to rotate with them.

A plasma is created within the vacuum chamber by applying a negative voltage from a power supply 40 to the sputtering surfaces with respect to the vacuum cham-

ber metal frame 11 or some other anode, which is usually connected to ground potential. The plasma is positioned adjacent a sputtering zone of the cylindrical sputtering targets 27 and 29, controlled by the positioning of their respective magnets (not shown in Figure 1). These magnets are positioned along the length of their respective cylindrical sputtering targets 27 and 29, while extending a small circumferential, or radial, distance therearound. These magnets are most conveniently held within the sputtering targets 27 and 29 by attachment to respective coolant conduits 43 and 45. These cooling conduits are provided as part of their respective target assemblies in a manner to be rotatable independently of rotation of their respective cylindrical sputtering targets 27 and 29.

Thus, the position of the magnets in each target assembly, and thus the position of the sputtering zone of each, is controlled by rotation of these cooling conduits. Specifically, a pulley 47 is attached to the conduit 43 and driven from an electrical motor source 49 outside the vacuum chamber by a toothed belt 51. Similarly, a pulley 53 is attached to the coolant conduit 45 and is controlled as to rotatable position by an electrical motor source 55 positioned outside the vacuum chamber and connected with it by a toothed belt 57. The motor sources 49 and 55 are preferably stepper motors which thereby hold their respective conduits 43 and 45 in selected positions and keep them from rotating with their respective sputtering targets 27 and 29.

A cooling liquid supply and exhaust system (not shown) outside the vacuum chamber provides coolant into the center of each of the conduits 43 and 45, as indicated by an arrow 61, and exhausts the heated coolant from a space between the outside of the conduits and an interior surface of the spindles, as indicated by an arrow 63. An electrical and electronic control

system 59 operates to control the power supply 40 and various parameters of the magnetron system being shown, including motors 31, 49 and 55.

The improvement of the present invention is implemented in the system of Figure 1 by providing cylindrically-shaped shield structures 67 and 69, or blocking means, around and spaced from each of the cylindrical target surfaces 27 and 29, respectively. Additionally, the cylinders extend in length beyond the end of the sputtering material in order to cover exposed surfaces of adjacent spindles and their supporting structures. Window openings 72 and 74, adjacent to respective shield structures 67 and 69, are large enough to expose the sputtering zone. These areas do not extend the full length of the cylindrical shield structures 67 and 69, however, leaving covered completely around their circumferences the respective sputtering surfaces 27 and 29 for a distance immediately adjacent the opposite ends of the sputtering material cylinder.

If the sputtering zone defining magnets inside the target assemblies are held fixed, the shield structures 67 and 69 are then most easily held with their windows in a fixed position. However, if the magnets are made to be rotatable, as described in the embodiment of Figure 1, such as is useful in the co-sputtering application previously mentioned, it is desirable to be able to controllably rotate the shield structures 67 and 69 so that their respective openings 72 and 74 follow the moving sputtering zone. The extent of shield structure rotation is made to be at least as great as the extent of magnet rotation. This allows the radial extent of the openings 72 and 74 to be kept small and thus maximize the coverage of the sputtering surface outside th sputtering zone. On the other hand, it is possible to make the radial extent of the openings 72 and 74 very large, thus allowing a limited rotation of

the magnets without having to rotate the shield structures. But maximum flexibility of operation is permitted, of course, when rotation of the shield structures 67 and 69 is provided over three-hundred-sixty degrees about the respective longitudinal axes of the cylindrically-shaped sputtering surfaces 27 and 29.

In order to accomplish such rotation, the shield structure 67 is provided with a pulley 71 around its circumference near one end, and the shield structure 69 is similarly provided with a pulley 73. An electrical motor source 75 rotates the shield structure 67 through a toothed belt 79, and a motor source 77 rotates the shield 69 through a toothed belt 81. The motor sources 75 and 77 are preferably stepper motors and are also controlled by connection with the control system 59.

Additional details of the target assemblies shown in Figure 1 are apparent from the views of Figures 2 and 4 of the target assembly 15. Elongated magnets 85, 87 and 89, of alternate polarity, are carried within the sputtering material cylinder 29 by a support structure 91 that is attached to the coolant tube 45. In this magnetic assembly, the sputtering tube 29 and the shield structure 69 are independently rotatable about a longitudinal axis 93 by respective motor sources 55, 31 and 77.

It will be noted from Figure 4 that a space exists between an outside surface of the target cylinder 29 and an inside surface of the cylindrically-shaped shield tube 69. Both these surfaces are, in cross-section, concentric circles that are separated by a distance that is significantly less than one inch, preferably less than substantially one-quarter inch. A small separation is required in order to avoid plasma from forming in the space between these two elements.

According to the present invention, shield structure 69 of Figure 2 is shaped at portions of its inner edges 70 that are adjacent to window openings 72 and 74 to conform to the contours of the magnetic field zone. The shape of the shield structure 69 is shown in Figure 2, while the method of designing the shape of the shield structure is fully described below in relation to Figure 6. The contoured shape of the shield structure 69 at inner edges 70 maximizes the self-cleaning characteristic of rotary cylindrical magnetrons according to a "race-track" pattern of etching, while minimizing the formation of condensate at the end portions of a cylindrical sputtering target assembly. A most important aspect of the invention is the shaping of the shield structure to minimize undesirable condensation of materials vaporized during the sputtering process, particularly dielectrics, and thereby reduce the often catastrophic arcing that results.

An alternative embodiment of the present invention is shown in Figure 3. Similar to the embodiment illustrated in Figure 2 comprised of shield structure 69, this alternative embodiment includes separate shield structures 69A and 69B positioned around and spaced from the target surface 29. Shield structures 69A and 69B are positioned at opposite ends of the target assembly 15 and are provided with pulleys 73A and 73B around their respective circumferences to be independently rotatable. According to the present invention, shield structures 69A and 69B are shaped at portions of their respective inner edges 70A and 70B that are adjacent to the opening 29 to conform to the contours of the magnetic field zone. It will be understood that the magnetron system, the magnetic assembly, the independent rotation, the supporting structure, and the shaping features of the invention described herein

are adapted to be equally applicable in the embodiment shown in Figure 3.

Referring to Figure 5, a specific supporting structure for a target assembly is given. A cylindrical sputtering surface 95 is carried through end spindles 97 and 99 in a manner to be rotatable about a longitudinal axis 101. A magnetic structure 103 is positioned within the target cylinder 95. As part of target supporting structures, plates 105 and 107 are provided at opposite ends of the target assembly. These end plates carry respective annular grooves 109 and 111 into which a cylindrically-shaped shield structure 113 is inserted at its ends. The shield structure 113 is then easily rotatable by a motor source connected to a pulley 115.

This support arrangement for the shield structure 113 also has an advantage of covering portions of the end plates 105 and 107 that are immediately adjacent ends of the sputtering target cylinder 95. These supporting structure surfaces are particularly susceptible to deposition of undesirable films on them, because of their proximity to the plasma sputtering zone, so are very useful for this purpose. Additionally, as previously mentioned, end portions 117 and 119 are circumferentially continuous around the shield structure and extend far enough along its length to cover respective end portions of the sputtering target 95 where the self-cleaning action of a rotating target acts as effectively as it does in more central portions of the target's length. A window 121 is provided, however, in the shield 113 to expose at least the sputtering zone. The shield structure 113 is preferably made of a material that itself has a low sputtering yield, such as stainless steel.

Prior to this invention, the design of cylindrical magnetron shield structures was based on the observation of the target structures after they had

undergone sputter etching in a rotary cylindrical magnetron in which the target structures were rotated. Because the target structures were rotated, the sputtering surface was observed as a uniformly etched surface with a band of deposited material at the ends of the target structure. Based on this observation, rotary cylindrical magnetrons were thought to avoid the problem of "race-track" etching of the sputtering surface, as observed in planar magnetrons with a fixed sputtering zone. See Kirs, Milan R., et al., "Cylindrical Magnetron Shield Structrure," U.S. Patent No. 5,108,574. Consequently, shield structures for such rotary cylindrical magnetrons were designed with rectangularly-shaped inner edges adjacent to the sputtering zone to shield the area at the ends of the target structure corresponding to the observed condensation band.

It has been discovered, however, that the sputtering surfaces of rotary cylindrical magnetrons are indeed etched in a well-defined "race-track" pattern, causing condensate build-up in a conforming pattern at the ends of the target structure. Referring to Figure 6, a cylindrical sputtering target 131 is shown after it has undergone sputter etching in a rotary cylindrical magnetron in which the target structures are held immobile. A "race-track" pattern on the sputtering surface bounded by boundary 139 indicates the area of the target surface lying between the region of maximum magnetic field strength 135 and boundary 139 that has been etched during the sputter etching process. Areas 143, 145, 147, and 149 on the sputtering surfrace, which conform to the "race-track" etch pattern, indicate the pattern of condensation at the end portions of the sputtering target. Such condensation occurs at positions on the sputtering surface where the rate of condensation exceeds the rate at which deposited condensate is removed by sputtering.

When a sputtering target exposed to condensation is further examined, there is evidence of significant damage to the target structure attributable to catastrophic arcing. Additionally, an examination of the coated substrate reveals similar evidence of damage to the coating attributable to arcing. By contrast, when a sputtering target is shielded from condensation using the shaped shield structures of the present invention, arcing is minimized and dagmage to the target structure and the substrate coating is significantly reduced.

In a preferred method of designing the cylindrically-shaped shield structure of the present invention, magnetic paper is positioned on the target surface during operation of the rotating cylindrical magnetron. Magnetic paper is commercially available from a number of sources, including Edmund Scientific Company of New Jersey. During operation, the magnetic paper is marked by isomagnetic lines indicating the configuration of the magnetic field zone. The shield structure is then shaped at its inner edges adjacent to the magnetic field zone to conform to the contours of the magnetic field zone, as indicated by the isomagnetic lines. In a preferred form, the resulting design takes the form of a curved, notched shape at the inner edges of the shield structure, as illustrated in Figures 2 and 3.

Alternatively, the cylindrically-shaped shield structure is designed according to the patterns of condensation and etching that are observable on the target structure after the rotary cylindrical magnetron has been operated with the target structure held stationary. Referring to Figur s 2, 3 and 6, the inner edges 70 in Figure 2 and 70A and 70B in Figure 3 of the shield structure are designed in a curved, notched shape that follows the contours of the areas of condensation

143, 145, 147 and 149 in Figure 6 appearing on the target surface. Similarly, the inner edges may be designed in a curved, notched shape that follows the contours of the "race-track" etch pattern 139 in Figure 6 as it appears at the ends of the target structure.

Once shaped, the inner edges of the shield structure are positioned at an optimum distance from the magnetic field zone so that condensation and subsequent arcing are minimized at the ends of the target without disturbing the plasma. In a preferred method of designing the shield structure, the shield structure of the present invention is positioned on the target ends, a fixed distance from the magnetic field zone. During operation, arcing activity is monitored using a strip chart recorder that is connected to power supply 40 of Figure 1. The recorder is used to record any reduction in voltage that occurs over time in response to arcing activity, with fewer voltage drops indicating less arcing activity in the magnetron system. This sequence is repeated with the shaped inner edges of the shield structure positioned at various distances from the magnetic field zone, until the optimum distance from the magnetic field zone is determined. In a preferred form, the shield structure is extended lengthwise toward the magnetic field zone such that the inner edges of the shield and the magnetic field zone are separated by this optimum distance.

The shield structure of the present invention provides for maximum self-cleaning in the sputtering zone and minimum condensation beyond the sputtering zone and thereby reduces arcing activity in a rotary cylindrical magnetron. Although the present invention has been described with respect to a preferred embodiment thereof, it will be understood that the invention is entitled to protection within the full scope of the appended claims.

IT IS CLAIMED:

1. A sputtering apparatus, comprising:

a magnetron having a vacuum chamber including therein at least one target structure with an outer cylindrically-shaped surface of sputtering material;

first and second support structures holding said target structure at opposite ends thereof such that said target structure is rotatable about its longitudinal axis;

a magnet assembly within said target structure that provides a magnetic field zone extending along a length of said sputtering material surface and extending a circumferential distance therearound; and

first and second cylindrical shields, said shields carried at opposite ends of said target structure by said first and second support structures and extended axially along said sputtering material surface to substantially cover the ends of said sputtering material surface, said first shield having an inner edge closest to said second shield and said second shield having an inner edge closest to said first shield, said inner edges adjacent to said magnetic field zone being shaped to conform substantially to the contours of said magnetic field zone.

2. The apparatus according to claim 1, wherein said first and second cylindrical shields are separated from said sputtering material surface by less than one inch.

3. The apparatus according to claim 1, wherein said first and second cylindrical shields are separated from said sputtering material surface by less than substantially one-quarter inch.

4. The apparatus according to claim 1, wherein each of said first and second cylindrical shields is additionally shaped with continuous portions around its circumference at each of said opposite ends that are positioned to cover said sputtering surface for a distance adjacent each of its said opposite ends and extend over adjacent portions of said first and second support structures.

5. The apparatus according to claim 1, wherein said inner edges of said shields are shaped to conform substantially to the shape of a pattern of condensation of vaporized material on said target structure when held stationary.

6. The apparatus according to claim 1, wherein said inner edges of said shields are shaped to conform substantially to the shape of a pattern of etching of sputtering material on said target structure when held stationary.

7. The apparatus according to claim 1, wherein said inner edges of said shields are positioned a distance from said magnetic field zone sufficient to stabilize arcing adjacent to said magnetic field zone.

8. The apparatus according to claim 1, wherein said shields are connected at corresponding portions of their inner edges which are not adjacent to said magnetic field zone by a cylindrically-shaped structure extending around a portion of the circumference of said sputtering material surface that is substantially outside said magnetic field zone to form a unified shield, said unified shield having an opening at least as large as said magnetic field zone and extending around a portion of the circumference of said sputtering

material surface that is substantially inside said magnetic fi ld zone and having a length less than a distance between opposite ends of said target structure sputtering surface.

9. A sputtering apparatus adapted to coat films on substrates within a vacuum chamber, comprising:

at least one elongated target having a sputtering surface with an outside cylindrical shape of a given diameter and a given length between first and second ends thereof;

first and second support structures respectively supporting said first and second sputtering surface ends in a manner that allows said target to rotate about a central longitudinal axis thereof;

means positioned within said target for providing a magnetic field zone extending along a length of said sputtering surface and a circumferential distance therearound;

electrically controlled driving means coupled to said target structure for rotating said sputtering surface through said magnetic field zone; and

first and second cylindrical shields separated by a distance of less than substantially one-quarter inch from said sputtering surface for minimizing condensation of sputtered material at said first and second sputtering surface ends, said shields carried at opposite ends of said target by said first and second support structures and extended axially along said sputtering surface to substantially cover the ends of said sputtering surface, said shields having continuous portions extending around the circumference of said first and second ends positioned to cover said sputtering surface for a distance adjacent each of its said first and second ends and extend over adjacent portions of said first and second support structures, said first

shield having an inner edge closest to said second shield and said second shield having an inner edge closest to said first shield, said inner edges adjacent to said magnetic field zone being shaped to conform substantially to the contours of said magnetic field zone.

10. The apparatus according to claim 9, wherein said inner edges of said shields are shaped to conform substantially to the shape of a pattern of condensation of vaporized material on said target structure when held stationary.

11. The apparatus according to claim 9, wherein said inner edges of said shields are shaped to conform substantially to the shape of a pattern of etching of sputtering material on said target structure when held stationary.

12. The apparatus according to claim 9, wherein said inner edges of said shields are positioned a distance from said magnetic field zone sufficient to stabilize arcing adjacent to said magnetic field zone.

13. The apparatus according to claim 9, wherein said shields are connected at corresponding portions of said inner edges which are not adjacent to the magnetic field zone by a cylindrically-shaped structure extending around a portion of the circumference of said sputtering surface that is substantially outside said magnetic field zone to form a unified shield, said unified shield having an opening at least as large as said magnetic field zone and extending around the portion of the circumference of said sputtering surface that is substantially inside said magnetic field zone

and having a length less than a distance between said first and second ends of said sputtering surface.

14. A method of forming cylindrical end shields for use in a sputtering apparatus comprised of a rotating cylindrical magnetron within a vacuum chamber including therein at least one rotatable target structure having an outer cylindrically-shaped surface of sputtering material and held at opposite ends thereof by first and second support structures, a magnet assembly within said target structure that provides a magnetic field zone, and first and second cylindrical end shields carried at opposite ends of said target structure by said support structures, said first shield having an inner edge closest to said second shield and said second shield having an inner edge closest to said first shield, said inner edges positioned adjacent to said magnetic field zone, comprising the steps of:

(a) operating said rotating cylindrical magnetron such that said magnetic field zone is provided;

(b) measuring said magnetifc field zone such that a magnetic field pattern is obtained; and

(c) shaping said shields at said inner edges to conform substantially to the isomagnetic lines of said magnetic field pattern.

15. A method of forming cylindrical end shields for use in a sputtering apparatus comprised of a rotating cylindrical magnetron within a vacuum chamber including therein at least one rotatable target structure having an outer cylindrically-shaped surface of sputtering material and held at opposite ends thereof by first and second support structures, a magnet assembly within said target structure that provides a magnetic field zone, and first and second cylindrical end shields

carried at opposite ends of said target structure by said support structures, said first shield having an inner edge closest to said second shield and said second shield having an inner edge closest to said first shield, said inner edges adjacent to said magnetic field zone, comprising the steps of:

(a) operating said rotating cylindrical magnetron such that said magnetic field zone is provided and said target structure is immobile;

(b) determining positions on said immobilized target structure where condensation of material vaporized during said sputtering operation has occurred; and

(c) shaping said shields at said inner edges to conform substantially to a pattern of said positions determined in step (b).

16. The method of any one of claims 14 and 15, additionally comprising the step of optimizing the distance between said shields and said magnetic field zone by placing said shaped shields on said opposite ends of a cylindrical sputtering structure, operating said rotating cylindrical magnetron, recording arcing activity using recording means, and adjusting said distance to minimize said arcing activity.

17. The method of any one of claims 14 and 15, additionally comprising the step of optimizing the distance between said shields and said magnetic field zone by placing said shaped shields on said opposite ends of a cylindrical sputtering structure, operating said rotating cylindrical magnetron, recording voltage within the vacuum chamber of the sputtering apparatus using recording means, and adjusting said distance to minimize variations in voltage adjacent to said magnetic field zone.

18. A method of any one of claims 14 and 15, additionally comprising the step of connecting said end shields at portions of said inner edges which are not adjacent to said magnetic field zone by a cylindrically-shaped structure extending around the portion of the circumference of a cylindrical sputtering structure that is substantially outside said magnetic field zone to form a unified shield, said unified shield having an opening at least as large as said magnetic field zone and extending around the portion of the circumference of said cylindrical sputtering structure that is substantially inside said magnetic field zone and having a length less than a distance between opposite ends of said cylindrical sputtering structure.

19. A method of any one of claims 14 and 15, additionally comprising the steps of:

(a) optimizing the distance between said shields and said magnetic field zone by placing said shaped shields on said opposite ends of a cylindrical sputtering structure, operating said rotating cylindrical magnetron such that said magnetic field zone is provided, recording arcing activity using recording means, and adjusting said distance to minimize said arcing activity; and

(b) connecting said end shields at portions of said inner edges which are not adjacent to said magnetic field zone by a cylindrically-shaped structure extending around the portion of the circumference of said cylindrical sputtering structure that is substantially outside said magnetic field zone to form a unified shield, said unified shield having an opening at least as large as said magnetic field zone and extending around the portion of the circumference of said cylindrical sputtering structure that is substantially inside said magnetic field zone and having a length less than

a distance between opposite ends of said cylindrical sputtering structure.

20. A method of any one of claims 14 and 15, additionally comprising the steps of:

(a) optimizing the distance between said shields and said magnetic field zone by placing said shaped shields on said opposite ends of a cylindrical sputtering structure, operating said rotating cylindrical magnetron such that said magnetic field zone is provided, recording voltage within the vacuum chamber of the sputtering apparatus using recording means, and adjusting said distance to minimize variations in voltage adjacent to said magnetic field zone; and

(b) connecting said end shields at portions of said inner edges which are not adjacent to said magnetic field zone by a cylindrically-shaped structure extending around the portion of the circumference of said cylindrical sputtering structure that is substantially outside said magnetic field zone to form a unified shield, said unified shield having an opening at least as large as said magnetic field zone and extending around the portion of the circumference of said cylindrical sputtering structure that is substantially inside said magnetic field zone and having a length less than a distance between opposite ends of said cylindrical sputtering structure.

21. A method of sputter etching a cylindrical sputtering structure using a sputtering apparatus comprised of a rotating cylindrical magnetron within a vacuum chamber including therein at least one rotatable target structure having an outer cylindrically-shaped surface of sputtering material and held at opposite ends thereof by first and second support structures, a magnet

assembly within said target structure that provides a magnetic field zone, comprising the steps of:

(a) operating said rotating cylindrical magnetron such that said magnetic field is provided; and

(b) blocking opposite ends of said target structure where condensation of vaporized material forms using blocking means, said blocking means shaped to conform to the shape of said condensation areas.

22. A method of sputter etching a cylindrical sputtering structure according to claim 21, wherein said blocking means extends around the portion of the circumference of said cylindrical sputtering structure that is substantially outside said magnetic field zone.

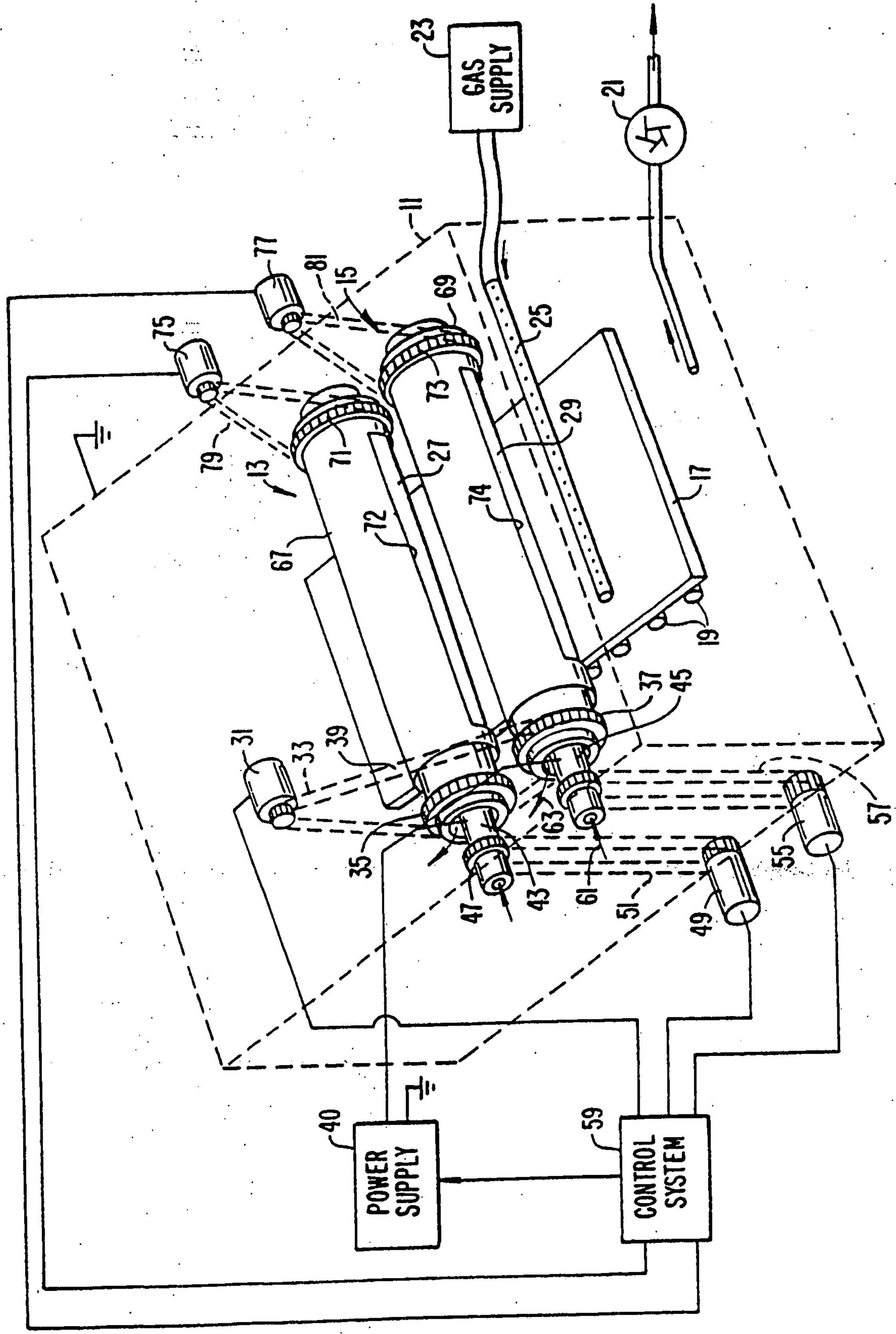

FIG. 1.

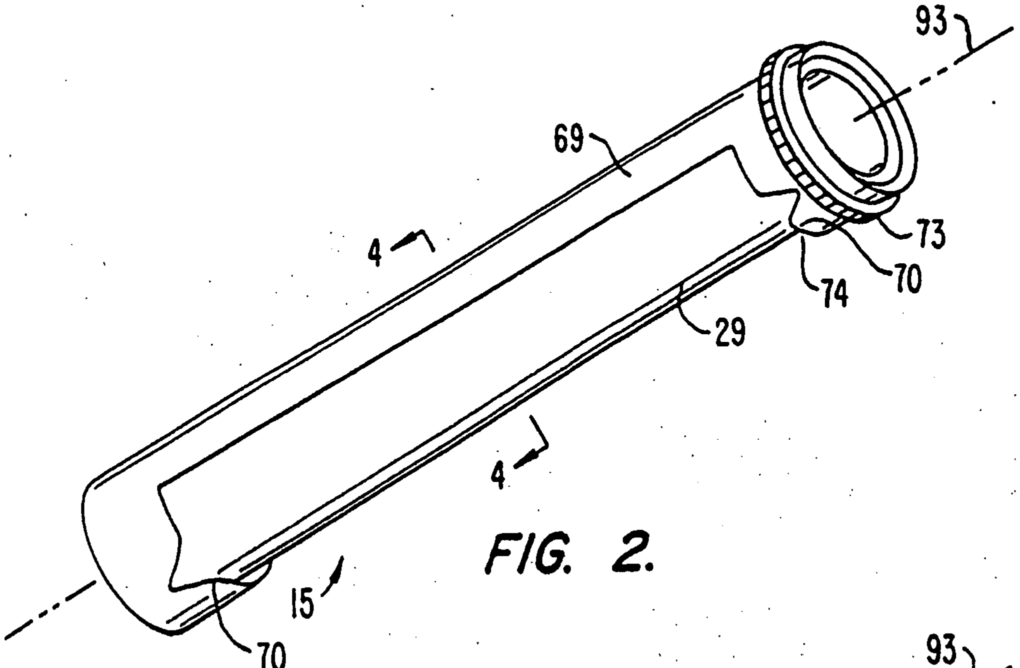

FIG. 2.

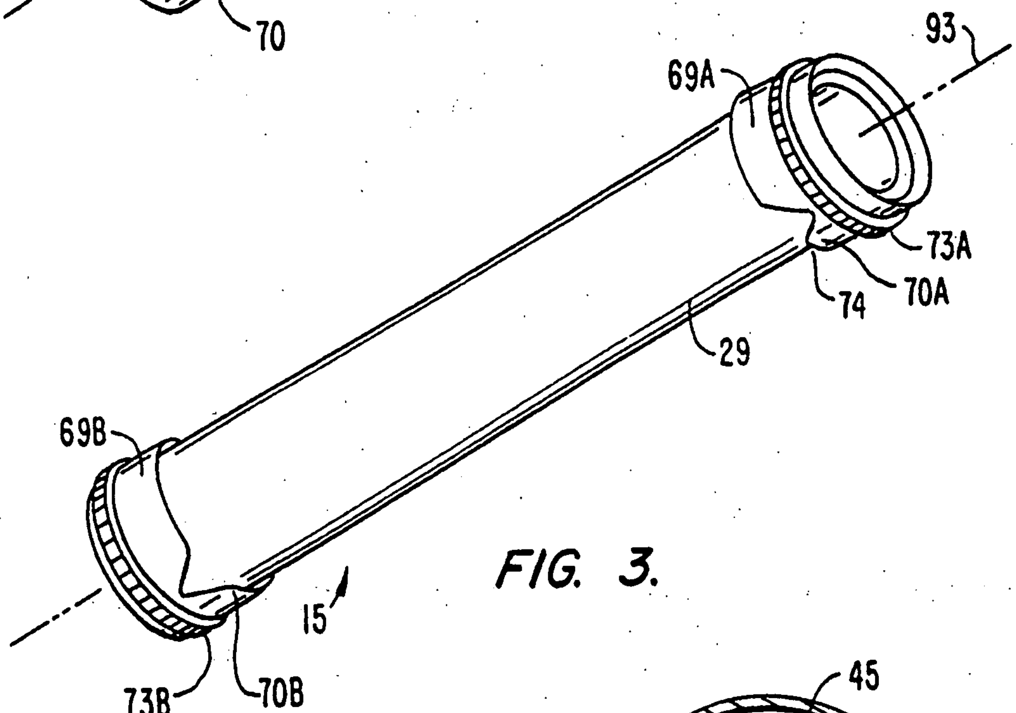

FIG. 3.

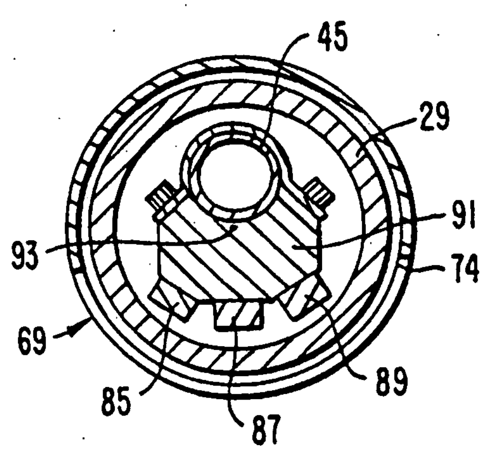

FIG. 4.

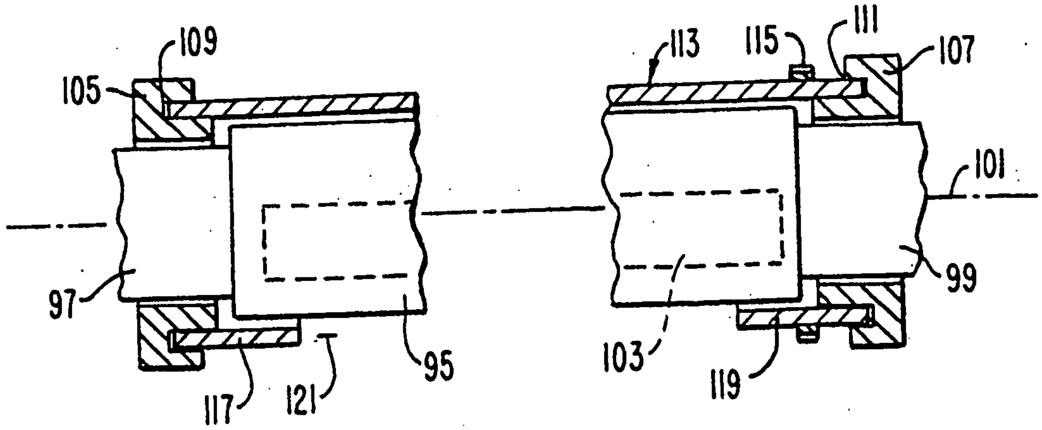
109
105
113
115
111
107
101
97
99
95
103
117
121
119

FIG. 5.

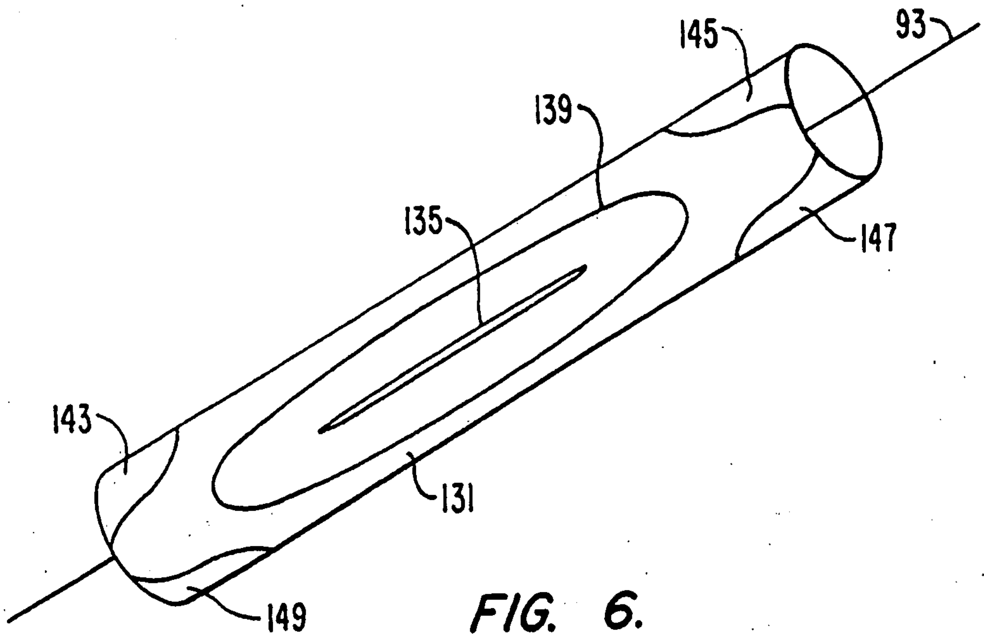
145
93
139
135
147
143
131
149

FIG. 6.

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) : C23C 14/34
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to b th national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classificati n system f llowed by classificati n symbols)

U.S. : 204/192.12, 192.32, 192.33, 298.03, 298.11, 298.21, 298.22, 298.22 298.31, 298.32, 298.37 and IPC(5) C23C 14/34

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US,A, 5,108,574 (KIRS ET AL), 28 April 1992, See figures 1-4	1-22
Y,P	US,A, 5,213,672 (HARTIG ET AL), 25 May 1993, See figures 1-7 and column 3 lines 5-32	1-22

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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21 MARCH 1994	11 APR 1994

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A. CLASSIFICATION OF SUBJECT MATTER:
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204/192.12, 192.32, 192.33, 298.03, 298.11, 298.21, 298.22, 298.22 298.31, 298.32, 298.37

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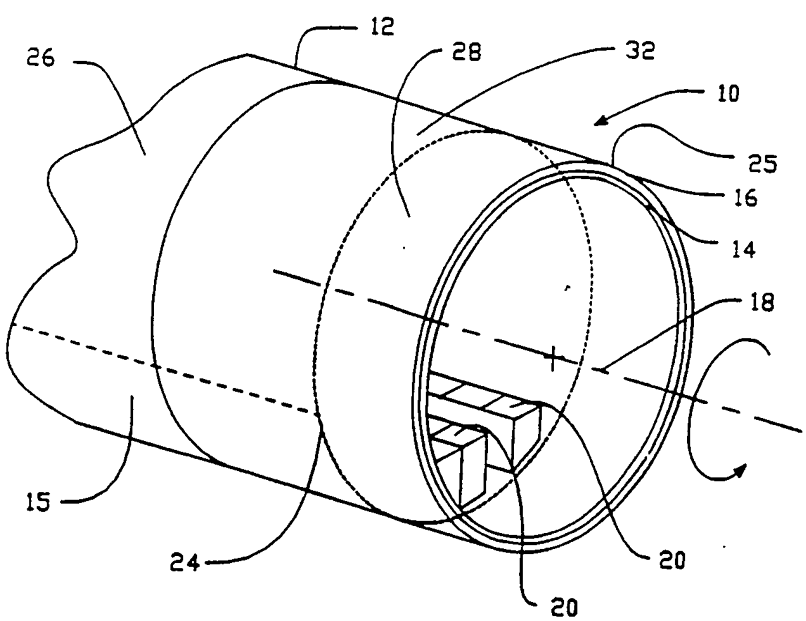
(54) Title: SHIELDING FOR ARC SUPPRESSION IN ROTATING MAGNETRON SPUTTERING SYSTEMS



(57) Abstract

A cathode body (12) for a rotating cylindrical magnetron (10) wherein the magnetron provides a sputtering zone extending along the length of the cathode body (12) and circumferentially along a relatively narrow region thereof. The cathode body (12) includes an elongated tubular member (14) having a target material (16) at the outer surface thereof. A collar (32) of electrically-conductive material is located at at least one end of the tubular member (14), and extends along the tubular member (14) from that one end into the erosion zone. A sleeve of electrically-conductive material may extend circumferentially around the collar (32).

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+ It is not yet known for which States of the former Soviet Union any designation of the Soviet Union has effect.

SHIELDING FOR ARC SUPPRESSION IN ROTATING MAGNETRON SPUTTERING SYSTEMS

Background of the Invention

The present invention relates generally to sputtering systems, and more particularly to sputtering insulating materials in a rotating cylindrical magnetron using a DC reactive sputtering method.

DC reactive sputtering is the process most often used for large area commercial coating applications, such as the application of thermal control coatings to architectural and automobile glazings. In this process, the articles to be coated are passed through a series of in-line vacuum chambers isolated from one another by vacuum locks. This may be referred to as a continuous in-line system or simply a glass coater.

Inside the chambers, a sputtering gas discharge is maintained at a partial vacuum at a pressure of about three millitorr. The sputtering gas comprises a mixture of an inert gas, such as argon, with a small proportion of a reactive gas, such as oxygen, for the formation of oxides.

Each chamber contains one or more cathodes held at a negative potential of about -200 to -1000 volts. The cathodes may be in the form of elongated rectangles, the length of which spans the width of the line of chambers. The cathodes are typically 0.10 to 0.30 meters wide and a meter or greater in length. A layer of material to be sputtered is applied to the surface of the cathodes. This surface layer or material is known as the target or the target material. The reactive gas forms the appropriate compound with the target material.

Ions from the sputtering gas discharge are accelerated into the target and dislodge, or sputter off, atoms of the target material. These atoms, in turn, are deposited on a substrate, such as a glass sheet, passing beneath the target. The atoms react on the substrate with the reactive gas in the discharge to form a thin film.

The architectural glass coating process was made commercially feasible by the development of the magnetically-enhanced, planar magnetron. This magnetron has an array of magnets arranged in the form of a closed loop and mounted in a fixed position behind the target. A magnetic field in the form of a closed loop is thus formed in front of the target plate. The field causes electrons from the discharge to be trapped in the field and travel in a spiral pattern, which creates a more intense ionization and higher sputtering rates. Appropriate water cooling is provided to prevent overheating of the target. The planar magnetron is further described in U.S. Patent No. 4,166,018.

A disadvantage of the planar magnetron is that the target material is only sputtered in the narrow zone

defined by the magnetic field. This creates a "racetrack"-shaped sputtering zone on the target. Thus, a "racetrack"-shaped erosion zone is produced as sputtering occurs. This causes a number of problems. For example, (1) localized high temperature build-up eventually limits the power at which the cathodes can operate, and (2) only about 25 percent of the target material is actually used before the target must be replaced. Another significant problem, affecting uniformity and stability, is the build-up of oxides on the target outside of the erosion zone. This leads to arc discharges which temporarily perturb the gas discharge conditions. The arcing problem is very severe when silicon dioxide is being deposited by reactive sputtering of silicon.

The rotary or rotating cylindrical magnetron was developed to overcome some of the problems inherent in the planar magnetron. The rotating magnetron uses a cylindrical cathode and target. The cathode and target are rotated continually over a magnetic array which defines the sputtering zone. As such, a new portion of the target is continually presented to the sputtering zone which eases the cooling problem, allowing higher operating powers. While this cooling is more effective it is still possible for rotating magnetron cathodes to reach a temperature sufficient to melt low melting point target materials such as tin, lead, or bismuth, particularly at the ends of the sputtering zone. It is at the ends where the power density is highest because of the "turn around" portion of the "racetrack".

The rotation of the cathode and target also ensures that the erosion zone comprises th entire circumference of the cylinder covered by the sputtering zone. This

increases target utilization and reduces arcing from the target within the erosion zone. The rotating magnetron is described further in U.S. Patent Nos. 4,356,073 and 4,422,916, the entire disclosures of which are hereby incorporated by reference.

The rotating magnetrons while solving some problems produced others. These problems include new arcing phenomena, which are particularly troublesome in the DC reactive sputtering of silicon dioxide and similar materials such as aluminum oxide and zirconium oxide. Insulating materials like silicon dioxide are particularly useful to form high quality, precision optical coatings such as multilayer, antireflection coatings and multilayer, enhanced aluminum reflectors. Such coatings would be much more economical to produce if they could be applied by an in-line, DC reactive sputtering process.

The true advantages of a continuous, in-line sputtering process, as far as operating efficiencies are concerned, are only realized if the process can be continuously operated to produce acceptable product. Perturbation of the sputtering conditions due to arcing is especially detrimental to cost effective operation, as any article being coated when an arc occurs will most likely be defective. For instance, the article may be contaminated by debris resulting from the arc, or it may have an area with incorrect film thickness caused by temporary disruption of the discharge conditions. Furthermore, the occurrence of arcs increases with operating time, and eventually reaches a level which requires that the system be shut down for cleaning and maintenance.

By way of example, in one rotating magnetron configuration, arcing from cathode ends and bearing structures while depositing silicon dioxide from a silicon target was experienced less than one hour after sputtering commenced. The occurrence of arcs increased rapidly with operating time, reaching a frequency of about one hundred arcs per minute in less than 2 hours. This caused permanent perturbation of the discharge conditions, requiring that the machine be shut down for maintenance. This rotating magnetron configuration is described in J. Hoffman, "DC Reactive Sputtering Using a Rotating Cylindrical Magnetron", Proceedings of the 32nd Annual Conference of the Society of Vacuum Coaters, pp. 297-300 (1989).

In view of the foregoing, an object of the present invention is to improve the effectiveness of the DC reactive sputtering process for silicon dioxide and other materials, which are highly insulating, when deposited by DC reactive sputtering.

Another object of the present invention is to substantially reduce or eliminate the occurrence of arcs in rotating cylindrical magnetrons.

A further object of the invention is to increase the deposition rate for low melting point target materials.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description or will be learned from practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentaliti s and combinations particularly pointed out in th claims.

Summary of the Invention

The present invention is directed to a cathode body for a rotating cylindrical magnetron wherein the magnetron provides a sputtering zone extending along the length of the cathode body and circumferentially along a relatively narrow region thereof. The cathode body includes an elongated tubular member having a target material at the outer surface thereof. Means exist at at least one end of the tubular member for suppressing arcing.

The primary means of suppressing arcing comprises a cylindrical region on each end of the cathode body which has a surface of a collar material different from the target material. The cylindrical region extends into the sputtering zone typically for a distance of about two inches. The collar material is sputtered as the target material is sputtered, but typically at a lower rate. The sputtered collar material forms films having poor insulating properties. These films deposit on the cathode ends, dark space shielding and support structures in preference to the material sputtered from the target. Electrical leakage through these poorly-insulating films significantly reduces charge build-up and arcing.

The rotating cylindrical magnetron may be disposed in evacuable coating chamber, and means may be provided for transporting an article past the sputtering zone to receive the sputtered material.

Brief Description of the Drawings

The accompanying drawings, which are incorporated in and constitute a part of the specification, schematically

illustrate a preferred embodiment of the invention and, together with the general description given above and the detailed description of the preferred embodiment given below, serve to explain the principles of the invention.

Figure 1 is a schematic view of a rotary cylindrical magnetron showing the sputtering zone and the erosion zone in relation to the magnetic array.

Figure 2 is a schematic longitudinal section through a coating chamber showing a rotary cylindrical magnetron cathode constructed in accordance with the principles of the present invention wherein the magnetron is supported at one end only.

Figure 3 is an enlarged schematic cross-section showing mounting of the shields.

Figure 4 is a view similar to Figure 2 with the magnetron supported at both ends.

Figure 5 is a schematic view of an embodiment of the present invention having a cathode body of reduced diameter at each end.

Figure 6 is a schematic view of an embodiment of the present invention having collars with a raised portion to protect the sleeves from contamination by sputtered material.

Figure 7 is a schematic view of an embodiment of the present invention with a sleeve mounted on the cathode body at each nd thereof.

Detailed Description of the Preferred Embodiments

The present invention will be described in terms of a number of different embodiments. Referring in detail to the drawings, wherein like reference numerals designate like parts in several figures, and initially to Figure 1, the principles of the present invention are illustrated.

As shown in Figure 1, a rotating or rotary cylindrical magnetron 10 comprises a cathode body 12 including a tube or tubular member 14 with a target material 16 at the tube's outer surface. As is known, a magnetic array or bars 20 extend within the cathode body along a portion of the length thereof. The cathode body 12 rotates about an axis 18 while magnetic array 20 remains stationary.

Normally, magnetic array 20 does not extend completely to the respective ends of cathode body 12. This is because the seals, cooling water conduits, and bearing members are attached at one end of the cathode body. As a result, the magnetron's sputtering zone 15 does not extend all the way to the ends of the cathode body.

As shown in Figure 1, sputtering zone 15 extends as far as circumferential line 24, roughly corresponding with the end of magnetic array 20. The rotation of the cathode body produces a uniform erosion zone 26 which extends around the circumference of cathode body 12. This leaves an unsputtered area 28 outside the erosion zone and beyond circumferential line 24. Area 28 thus extends from circumferential line 24 to the end 25 of cathode body 12. A similar unsputtered area (not shown) exists at the opposite end of the cathode body. Thus, the cathode body ends are not sputtered. As such, an

oxide film is built up at the ends which, sooner or later, depending on the material being sputtered, will produce arcing from these unsputtered areas of the cathode body.

By way of example, a cathode body may be about 54 inches long and about 6 inches in diameter. The magnetic array can have a length of about 51 inches. As such, the sputtering and erosion zones would then have a length of approximately 52 inches. The unsputtered zone then extends about 1 inch along the cathode body at each end thereof.

Some materials, such as titanium oxide, zinc oxide, and indium tin oxide, when reactively sputtered form crystalline films having poor dielectric properties or even semiconductive properties. When these films accumulate on the unsputtered areas of the cathode, charges can easily leak through them. This prevents a charge build-up which may otherwise produce arcing. Only when such films are relatively thick, on the order of several microns, will arcing be a problem. This, however, may not occur until after several hours of operation.

Silicon dioxide films, reactively sputtered from silicon, however, deposit in a substantially amorphous form and are excellent electrical insulators. Reactively sputtered films of aluminum oxide and zirconium oxide have similar properties. When such insulating films form on the unsputtered areas of the cathode, for example beyond circumferential line 24, positive charges can build-up rapidly. Thus, an arc may be produced when the insulating film breaks down under the high electrical field produced by the charge

accumulation across the film. The better the insulating properties, the more rapidly will arcing occur, generally within an hour of operation.

As shown in Figure 1, the present invention, in its simplest form, includes a collar 32. The collar 32 is in contact with cathode body 12, and extends beyond circumferential line 34 into erosion zone 26. Preferably, and by way of example, when sputtering silicon, the collar extends approximately two inches into the erosion zone. Such a collar is formed at each end of the collar body.

The collar material should have a high melting point. A high melting point reduces the chance of damage to the collar when an arc does occur. Damage on the collar would provide sites which might initiate further arcing.

The collar material should form a compound with the reactive component of the sputtering gas. For example, the compound may be an oxide or a nitride of the collar material. Such compounds form films having poor insulating properties. Charge leakage should occur through these films even if tens of microns thick.

The collar material should have a lower sputtering rate than the target material. Material sputtered from the collar material will be deposited not only on the cathode ends and support structures, but also on the edges of a substrate being coated where it will be mixed with material sputtered from the target. It is desirable to ke[illegible] the ratio of sputtered collar material to sputtered t[illegible]get material on the substrate edges as low as possib[illegible]. The sputtering rate of the collar material can not, however, be zero. Otherwise,

sputtered target material would eventually deposit on the support structures and cause arcing. Sputtering from the collar does not prevent material sputtered from the target from reaching these support structures. Rather, it ensures that the sputtered target material is mixed with the sputtered collar material which destroys the insulating properties of the sputtered target material.

Any collar material will be useful to some degree provided that when sputtered it has a lesser tendency to arc than the sputtered target material under the same conditions. Suitable collar materials include scandium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, zirconium, molybdenum, hafnium, tantalum. tungsten, rhodium, platinum, and iridium. It has been found that titanium is an ideal collar material when sputtering silicon dioxide from a silicon target.

A further benefit derived from a high melting point collar material is that the collar can be extended into the sputtering zone to cover the "turnaround" of the "racetrack" shaped sputtering zone where the power deposited on the cathode is highest. If the target material is a low melting point material, higher power can be applied to the cathode body before the melting point of the target material in reached. Higher deposition rates for low melting point materials are, therefore, achievable using such collars on the cathode body.

A number of options for applying collar 3?
of cathode body 12 are available.
it is not necessary that the
s parate cylindrical unit

Rather, the term collar as used in the context of the present invention means a cylindrical region around the ends of the cathode body wherein the collar material is different from the target material. For example, if tubular member 14 is made from a suitable collar material. A collar may be formed by removing the target material from the tubular member 14 such that an appropriate section or sections are left exposed to form a collar or collars. If tubular member 14 is made from the target material, an additional layer of material would have to be applied to the target material to form the collar.

There is no specific formula for determining the extent to which the collar extends into the sputtering zone. The further the extension than the less will be the possibility that material sputtered from the target will reach the cathode body ends and the support structures. The further the extension, however, the narrower will be the target region and thus the narrower the substrate which can be coated with sputtered target material. The collar and target materials involved will also influence the determination. An extension of 2 inches for titanium collars used with silicon represents a value that was experimentally determined, and which can be used as a guideline when dealing with other materials.

In certain mounting configurations for a cylindrical magnetron, it is helpful to enclose the ends of the cathode body with a dark space shield. This reduces arcing. Such shields are discussed below. It has been found, however, that without the addition of the collars to the cathode body, the dark space shields rapidly become contaminated with coating material and become arc sources.

The collar, therefore, appears to be the most effective measure in reducing arcing. In combination with dark space shielding over the cathode body ends, the collars have been found to substantially eliminate arcing during the reactive sputtering of silicon dioxide.

For example, a dark shield or sleeve may be concentrically disposed about cathode body 12 and spaced from its surface. The shield may extend from end 25 of the cathode body a distance approximately equal to the dark space length (discussed below) and may extend to the edge of the sputtering zone, up to or just past circumferential line 24. The shield would thus encircle the end of the cathode body and the corresponding portion of collar 32.

The shield is spaced from collar 32 to form a gap. The distance across this gap is less than the dark space length. The dark space is the region of gas discharge next to the cathode. Here, the electrons accelerate under an applied operating voltage to become adequately energized to cause ionization of the sputtering gas. The dark space length is a function of the type of sputtering gas, the gas pressure and the applied electric field. The dark space length may be on the order of three millimeters.

The dark space shield protects the cathode body from the gas discharge and resultant ion bombardment. The shield around the end of the cathode body may prevent the sputtering gas discharge from contacting that end. The shield has a provision, such as a flange, for attachment to an appropriate support member, as will be described below. The shield is also insulated from this mounting surface so that it is el ctrically-isolated ther from.

Thus, it floats electrically and acquires an electrical potential of the gas discharge. A preferred material for the shield is stainless steel.

As shown in Figure 2, a rotating cylindrical magnetron 40 may be mounted in a cantilevered fashion within an evacuable coating chamber 44. As is known, the substrates S to be coated pass beneath cylindrical magnetron 40 on compound rollers 41. The substrates may be coated with a thin film of silicon dioxide or other material.

The cylindrical magnetron 40 includes a cathode body 43 mounted to a rotatable vacuum seal unit 42. As is known in the art, unit 42 provides an arrangement by which the cathode body may be rotated while maintaining a vacuum in coating chamber 44. The vacuum unit 42 also provides the necessary electrical, mechanical and fluid connections between magnetron 40 and the area outside the vacuum chamber. The vacuum unit 42 is disposed and sealed by a flange 54 in an opening in side wall 50 of chamber 44. The coating chamber is sealed by a top cover 46 having an appropriate vacuum seal 48. The top cover spans the distance between respective side walls 50 and 52 of chamber 44. As is known, magnetron 40 may be installed in and removed from chamber 44 through top cover 46.

The drive for rotating cathode body 43 is provided by an electric motor 56 mounted on a support bracket 58. The drive is transmitted to the cathode body by pulleys 60 and 62, and a drive belt 64.

Cooling water is fed into the cathode body through a stationary tube or conduit 66. As shown, tube 66

extends from coating chamber 44 to a location external thereof by means of vacuum eal unit 42. The tube 66 also supports magnetic array 70 which is attached to the tube by appropriate brackets 72. The cooling water is removed via a tube or conduit 68 which also passes through vacuum seal unit 42. Tube 68 also carries the necessary electrical connections for magnetron 40.

As is known, the end of the cathode body adjacent vacuum unit 42 is sealed by a sealing plug 78. The cooling water tubes 66 and 68 extend through this plug. A sealing plug 80 is located at the opposite end of the cathode body. It is recessed to provide a bearing 82 about which the cathode body rotates.

As noted, substrates S are transported past cylindrical magnetron 40 on compound rollers 41. The rollers are mounted on a shaft 100 which rotates in bearings 102. The bearings, in turn, are mounted on the floor or base plate 51 of the coating chamber. A series of such roller shafts separated from each other by a distance of about one foot may extend along the length of coating chamber 44 in the direction of transport of the substrates. They are rotated by a chain drive system, which is not shown.

As previously discussed, cathode body 43 comprises a tubular member 74 having a target material 76 at the outer surface thereof. The tubular member may be formed of the target material, or a target material may be sprayed-coated onto a tubular member comprised of a non-target material such as stainless steel.

In this mbodiment, collars 92 and 94 are formed at each end of cathode body 43 (see also Figure 3). As

discussed, the collars extend from the respective ends of the cathode body into the erosion zone. Preferably, each collar 92, 94 extends into the erosion zone by a distance of approximately two inches for silicon sputtering.

Dark space shields or sleeves 84 and 88 are concentrically disposed about collars 92 and 94, respectively, at each end of cathode body 43. The sleeves extend along the cathode body for at least one dark space length. The dark space length is the distance that an electron must travel under the applied cathode potential and gas pressure before it acquires enough energy to initiate ionization of the gas. For a voltage of about 500 volts and a sputtering pressure of about 3 millitorr, the dark space length is about 3 mm.

As shown more clearly in Figure 3, sleeve 84 is mounted to the face of vacuum seal unit 42 by means of insulated bushings 47 and screw 49. An electrical insulator 86, such as nylon, is disposed between the sleeve and the surface of the vacuum unit. Thus, the sleeve is electrically isolated from the vacuum unit.

At the other end of the cathode body, sleeve 88 is attached to the end plug 80 by means of insulating bushings 81 and screw 83 An electrical insulator 90, such as nylon, is disposed between the plug 80 and sleeve 88 at the point at which the sleeve is attached to the plug 80 to electrically isolate the sleeve from the member.

Also, as previously discussed, gaps 83, 85 are formed between sleeves 84, 88 and collars 92, 94, respectively,

The distance across these gaps is less than the dark space length. As such, contact between the sputtering gas discharge and the unsputtered zone on the cathode body is reduced.

For certain applications, the shield and collar arrangement may be located at only one end of the cathode body. Also, in some applications, the sleeves need not be electrically insulated from their mounting surface. In certain mounting configurations, the dark space shields or sleeves may be unnecessary.

Another embodiment of the present invention is shown in Figure 4. Here, cathode body 143 of rotating magnetron 140 is mounted to end blocks 114 and 116 in coating chamber 120. The end blocks house the bearings, electrical and water connections for magnetron 140. As is known, end blocks 114 and 116 are mounted at top wall or cover 110 of chamber 120 by means of appropriate vacuum seals 117. The top wall 110 is sealed to side walls 121 and 123 of the chamber by vacuum seals 112.

The cathode body 143 is driven by an electrical motor 118 mounted at chamber top wall 110 by a support bracket 138. The motor drive is transmitted by a shaft 120 to a gearbox 122. A shaft 124 extends from the gear box into the end block 116 where it is mechanically linked to cooling water tube or conduit 128. Tube 128 is the output tube for the cooling water. The cooling water input tube 130 serves as the support for the magnetic bar or array 132. This tube also extends from end block 116. The magnetic bar 132 is mounted to tube 130 by a bracket arrangement 134. Fluid connections 126 are also provided on end block 116 to introduce water into tube 130 and to flow water from tube 128 by means of seals

(not shown) inside block 116. A connection 154 at end block 114 is also provided to introduce electrical power to the magnetron. This is done through a brush contact within block 114 by way of a drive spindle 170.

The cathode body 143 comprises tubular member 144 having a target material 142 at the outer surface thereof. The cathode body is sealed by plugs 160 and 162 at the respective ends thereof. Plug 160 is penetrated by tube 128, and plug 162, which has a bearing 178 for tube 130, is attached to drive spindle 170.

Collars 146 and 148 are located at each end of the cathode body. A sleeve 150 is attached to end block 114 and isolated from it by electrical insulator 172. A sleeve 152 is also attached to end block 116 and insulated from it by insulator 174.

As discussed in reference to the above embodiments, sleeves 150 and 152 extend along the length of the tubular member for at least one dark space length. The collars 146 and 148 extend into the erosion zone. Respective gaps 155 and 157 are formed between collars 146, 148 and sleeves 150, 152. The distance across each gap is less than the dark space length. The mounting arrangement for these collars and sleeves is like that shown at the drive end of the magnetron of Figure 3A.

Another embodiment of the present invention is shown in Figure 5. Here, cathode body 190 of rotating magnetron 195 is shown as mounted in a cantilevered fashion. The advantages offered by this embodiment, however, are equally applicable to a double-ended mounting configuration.

As shown, cathode body 190 has its diameter reduced at each end. Collars 192 and 193 at each end are shaped to conform to the contour of the cathode body. A sleeve 194 is mounted on a support member 196, such as the face of a vacuum sealing unit. The sleeve is electrically isolated from support member 196 by insulator 198. The sleeve's outside diameter is equal to or less than the larger outside diameter of the cathode body. The sleeve extends around collar 193.

At the free end of the cathode body, a sleeve 202 is mounted on sealing plug 214 and electrically isolated from the cathode body by insulator 204. Sleeve 202 is arranged around collar 192 in the same manner as sleeve 194. The magnetic array 208, and water cooling tubes 210 and 212 are also shown.

The gaps 200, 201 between the respective shields and collars is less than the cathode dark space length under normal sputtering conditions. In this embodiment, the entrances to gaps 200 and 201 are below the level of the cathode body. Thus, there is no line of sight contact between the gaps and target material 206 on the outer surface of the collars 192. As such, there is no direct access to gaps 200 and 201 for material sputtered from the target.

Yet another embodiment of the present invention is shown in Figure 6. Here, cathode body 210 comprises tubular member 220 with target material 222 at the outer surface thereof. Collars 224, 226 with raised beaded sections or portions 224a, 226a adjacent the target material are provided. The beads 224a, 226a are made high enough to prev nt sputtered material from entering gaps 200, 201 between sl eves 194, 202 and collars 224, 226,

respectively. The beads help to protect the shields from contamination.

It will be apparent to those skilled in the art that the concepts described in this embodiment can also be applied to a double-ended mounting configuration.

Yet another embodiment of the invention is shown in Figure 7. This embodiment provides an arc suppression system fully integrated into cathode body 230. The cathode body comprises tubular member 232 having target material 234 at the outer surface thereof. As previously described, collars 236, 238 are attached at opposite ends of the tubular member. A sleeve 240 is mounted on plug 242 by screws and electrically-isolated from the plug by an insulator 244. A second sleeve 246 is mounted on plug 272 and electrically-isolated by insulator 250 in the same way as shown at the free end of the magnetron of Figure 3A. Clearance, typically less than the dark space length, is provided between the shield, and spindle 252 and a cathode support member. The cathode support members may be end blocks 116 and 114, as shown in Figure 4. A drive spindle 252 extends from end block 116, and conduits 210 and 212 extend from end block 114.

The present invention has been described in terms of a number of embodiments. The invention, however, is not limited to the embodiments depicted and described. Rather, the scope of the invention is defined by the appended claims.

WHAT IS CLAIMED IS:

1. A rotating cylindrical magnetron sputtering apparatus for sputtering thin films of a selected coating material on a substrate using a gas discharge, comprising: an evacuable coating chamber; a cathode including an elongated cylindrical tubular member having a layer of target material at the surface thereof and having a sputtering zone extending along the length of said tubular member and circumferentially along a relatively narrow region thereof, said sputtering zone defining an erosion zone about said tubular member and along the length thereof; means for rotatably supporting said tubular member in said coating chamber; means for transporting an article past the sputtering zone to receive the sputtered material; and means on at least one end of said tubular member for suppressing arcing.

2. The apparatus of Claim 1 in which said arcing suppressing means includes at least one collar of electrically-conductive material around the one end of said tubular member, said collar having an end substantially flush with the one end of said tubular member and the other end extending into the erosion zone a distance sufficient to minimize the deposition of coating material on the one end of said tubular member and on the support structure thereof.

3. The apparatus of Claim 2 in which the arcing suppressing means further includes at least one cylindrical sleeve; means for mounting said sleeve so that it is positioned substantially concentrically around said collar with a gap therebetween being less than the cathode dark spac length, and said sleeve

extending along said cathode for at least one dark space length.

4. The apparatus of Claim 3 in which said sleeve is mounted on a support means for the cathode.

5. The apparatus of Claim 4 in which said sleeve is electrically-isolated from said support means.

6. The apparatus of Claim 3 in which said sleeve is mounted on the cathode and electrically-isolated therefrom.

7. The apparatus of Claim 3 in which said collar has a raised portion around the circumference thereof to minimize deposition of coating material on said sleeve.

8. The apparatus of Claim 3 in which the diameter of said tubular member is reduced at the end covered by said sleeve to minimize deposition of coating material in the gap therebetween.

9. The apparatus of Claim 2 in which the material to be sputtered is selected from the group consisting essentially of silicon, aluminum, zirconium, tantalum, and an alloy of tin and zinc.

10. The apparatus of Claim 9 in which the collar material is selected from the group consisting essentially of scandium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, zirconium, molybdenum, hafnium, tantalum, tungsten, rhodium, platinum and iridium.

11. The apparatus of Claim 2 in which the tubular member has a collar at each end thereof.

12. The apparatus of Claims 1 or 2 in which the material to be sputtered is a low melting point material.

13. The apparatus of Claim 12 in which the collar material is selected from the group consisting essentially of scandium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, zirconium, molybdenum, hafnium, tantalum, tungsten, rhodium, platinum and iridium.

14. A cathode body for a rotating cylindrical magnetron wherein the magnetron provides a sputtering zone extending along the length of the cathode body and circumferentially along a relatively narrow region thereof, comprising: an elongated tubular member having a target material at the outer surface thereof; and on at least one end of said tubular member a collar of electrically-conductive material extending along the length of said tubular member from said one end thereof into said sputtering zone.

15. The cathode body of Claim 14 in which the collar has a raised section around the circumference thereof.

16. The cathode body of Claim 14 in which said tubular member has a reduced diameter at least one end thereof.

17. The cathode body of Claim 14 in which the tubular member has a reduced diameter at each end thereof.

18. The cathode body of Claim 16 or 17 in which said collar conforms to shape of the reduced diameter.

19. The cathode body of Claims 14 or 15 in which said collar is located at each end of said tubular member.

20. The cathode body of Claim 14, 15, 16, or 17 in which said target material is selected from the group consisting essentially of silicon, aluminum, zirconium, tantalum, and an alloy of tin and zinc.

21. The cathode body of Claim 20 in which said collar is formed from a material selected from the group consisting essentially of scandium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, zirconium, molybdenum, hafnium, tantalum, tungsten, rhodium, platinum and iridium.

22. The cathode body of Claims 14, 15, 16, or 17 in which said target material is a metal with a melting point less than about 700°C.

23. The cathode body of Claim 22 in which said collar is fabricated of a material selected from the group consisting essentially of scandium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, zirconium, molybdenum, hafnium, tantalum, tungsten, rhodium, platinum and iridium.

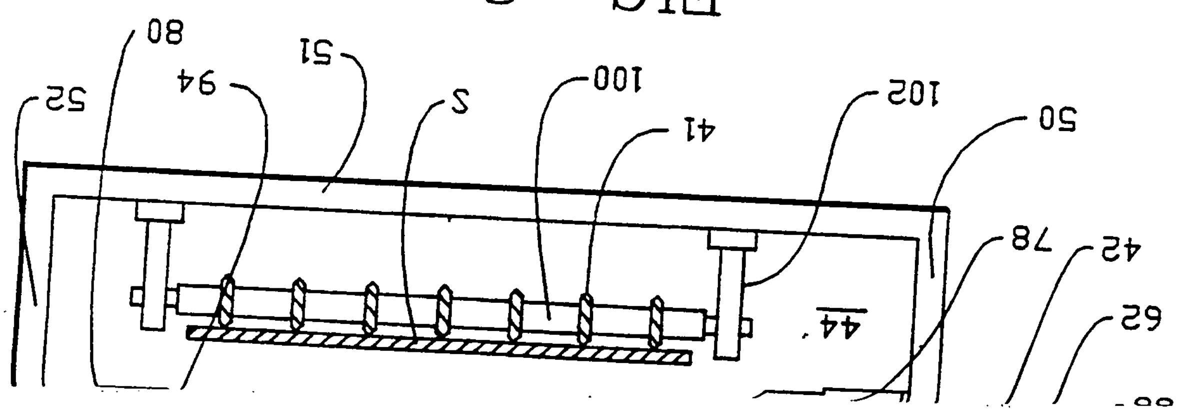
24. The cathode body of Claim 14 further including means for rotatably mounting the cathode body within an evacuable coating chamber.

25. The cathode body of Claim 14 wherein one of said tubular member ends fits in a sleeve.

26. A rotating cylindrical magnetron for sputtering thin films of a selected coating material, comprising: an elongated cylindrical tubular member including a magnetic means for defining a sputtering zone extending along the length and circumferentially along a relatively narrow region of said tubular member; and a collar of electrically-conductive material on at least one end of said tubular member and extending circumferentially about said tubular member, said collar extending from said one end into said sputtering zone.

27. The rotating cylindrical magnetron of Claim 26 further including a sleeve of electrically conductive material extending circumferentially about at least one end of said tubular member, said sleeve extending along said tubular member for at least one dark space length.

FIG.—2



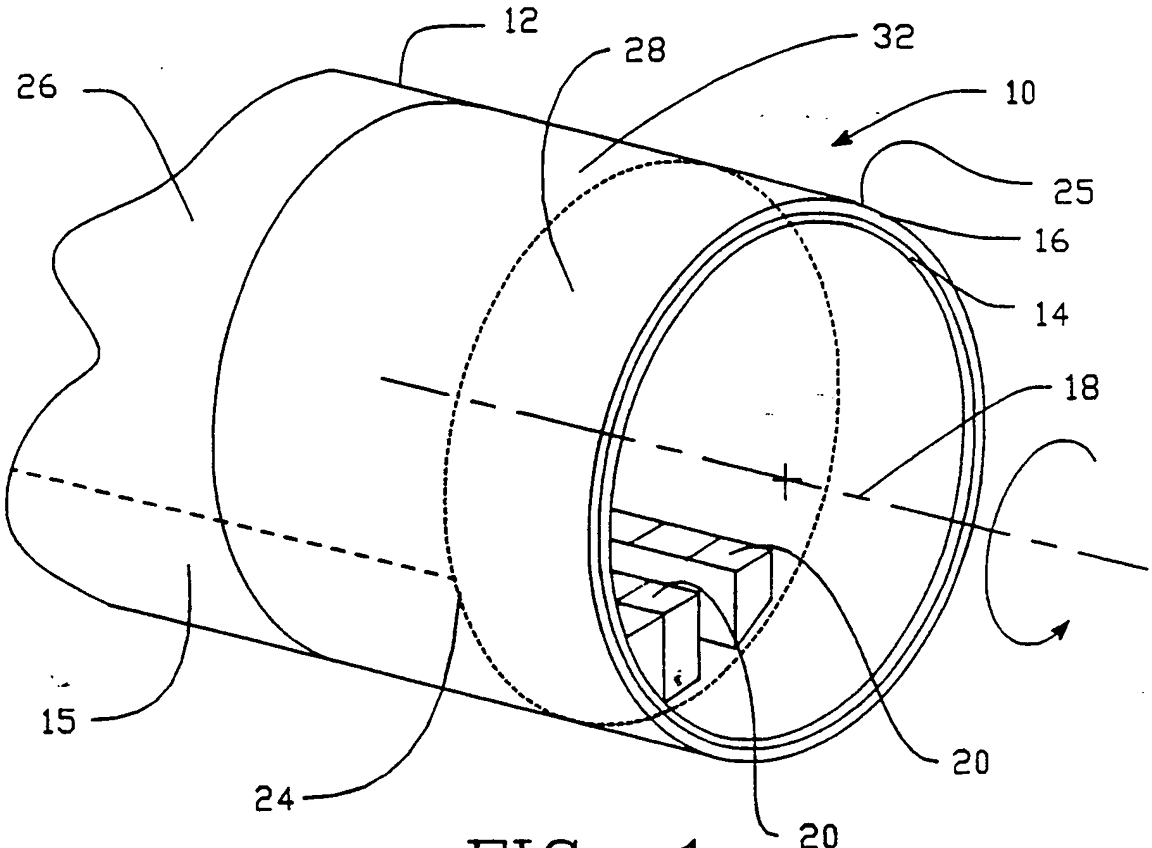

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FIG.—1

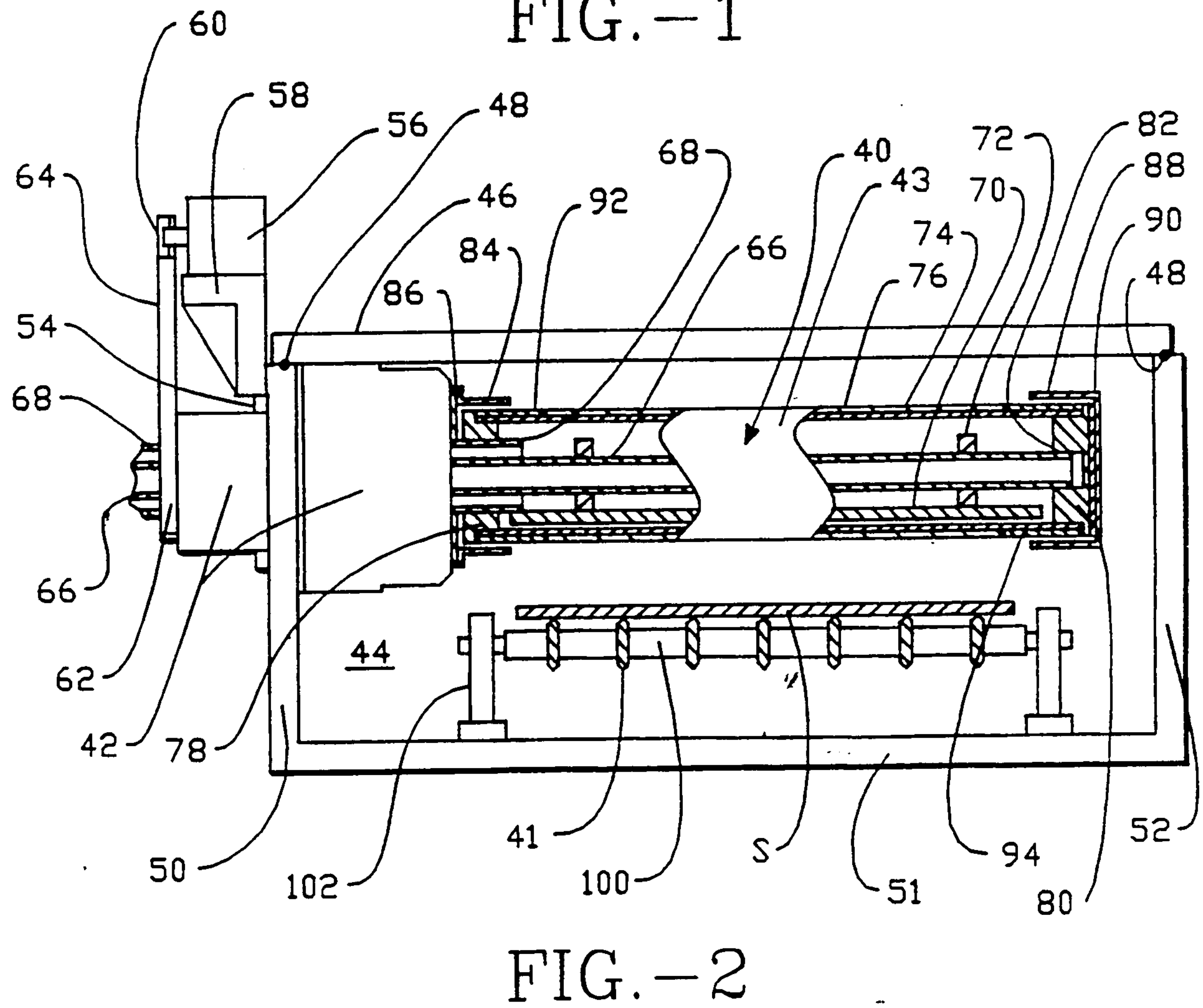
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FIG.—2

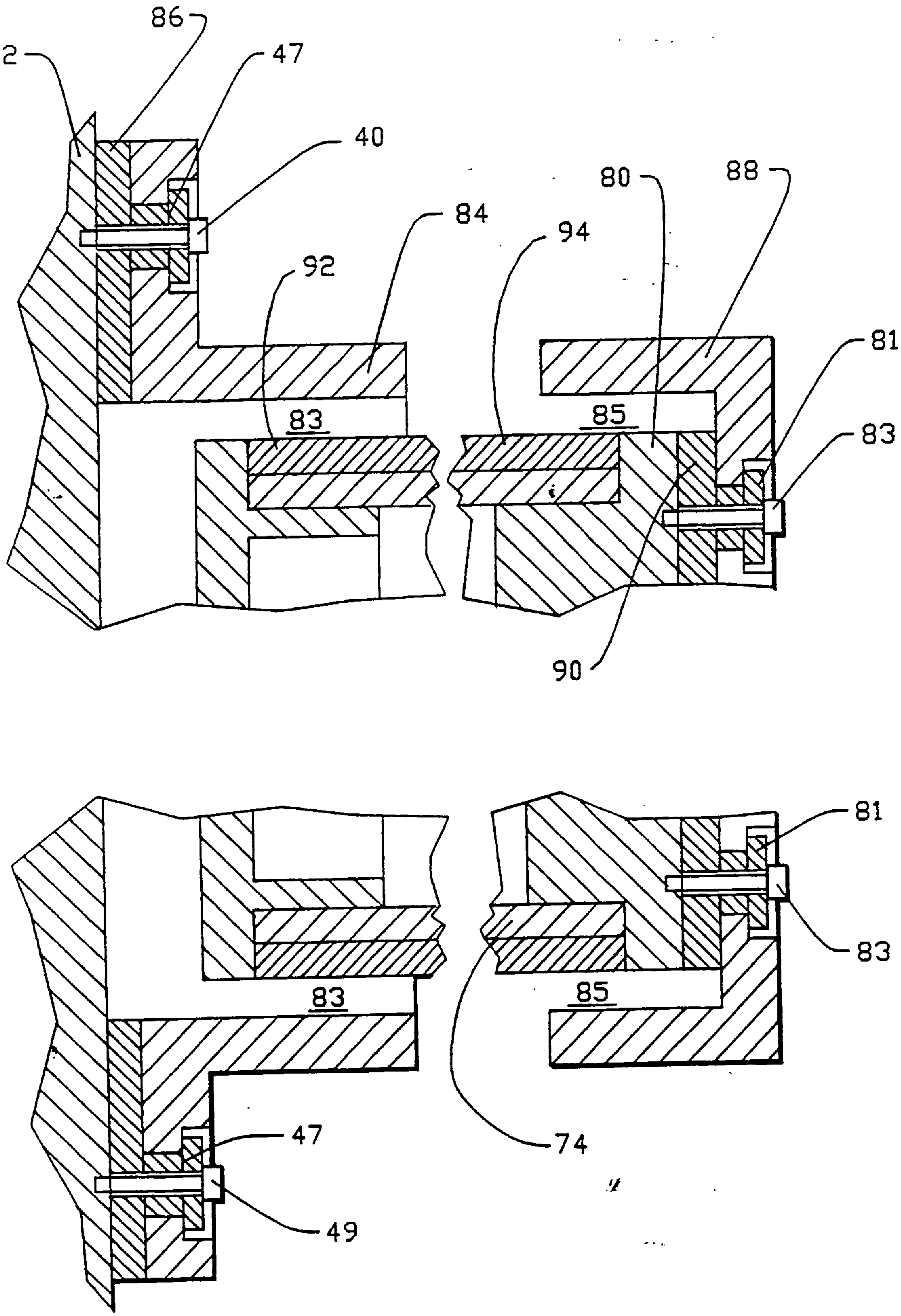

FIG.—3

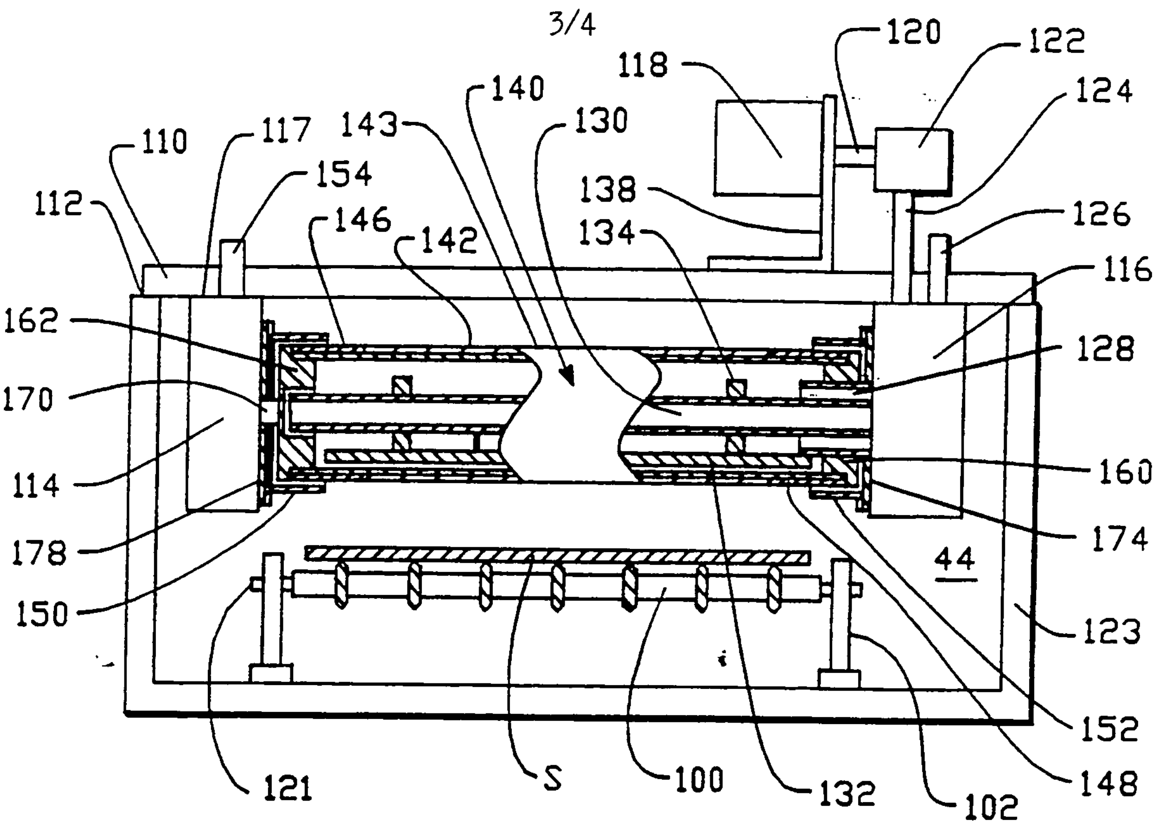
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FIG.—4

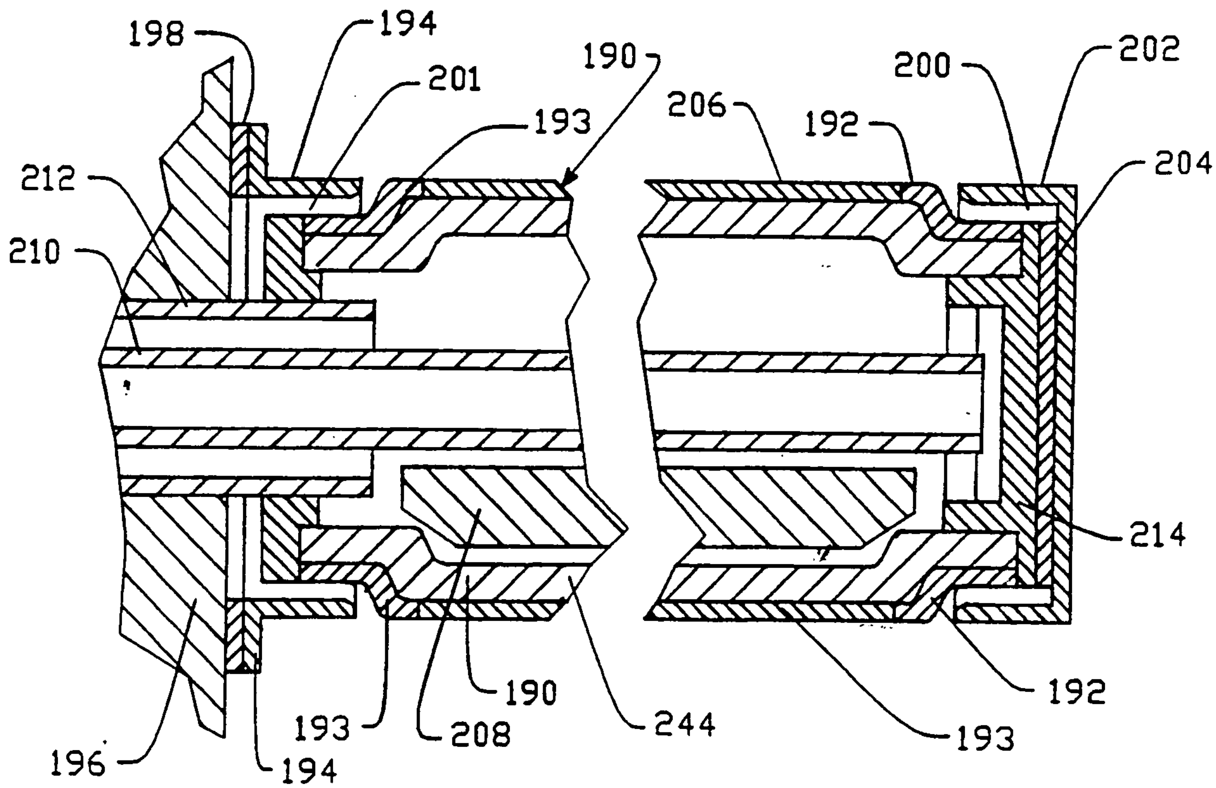
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FIG.—5

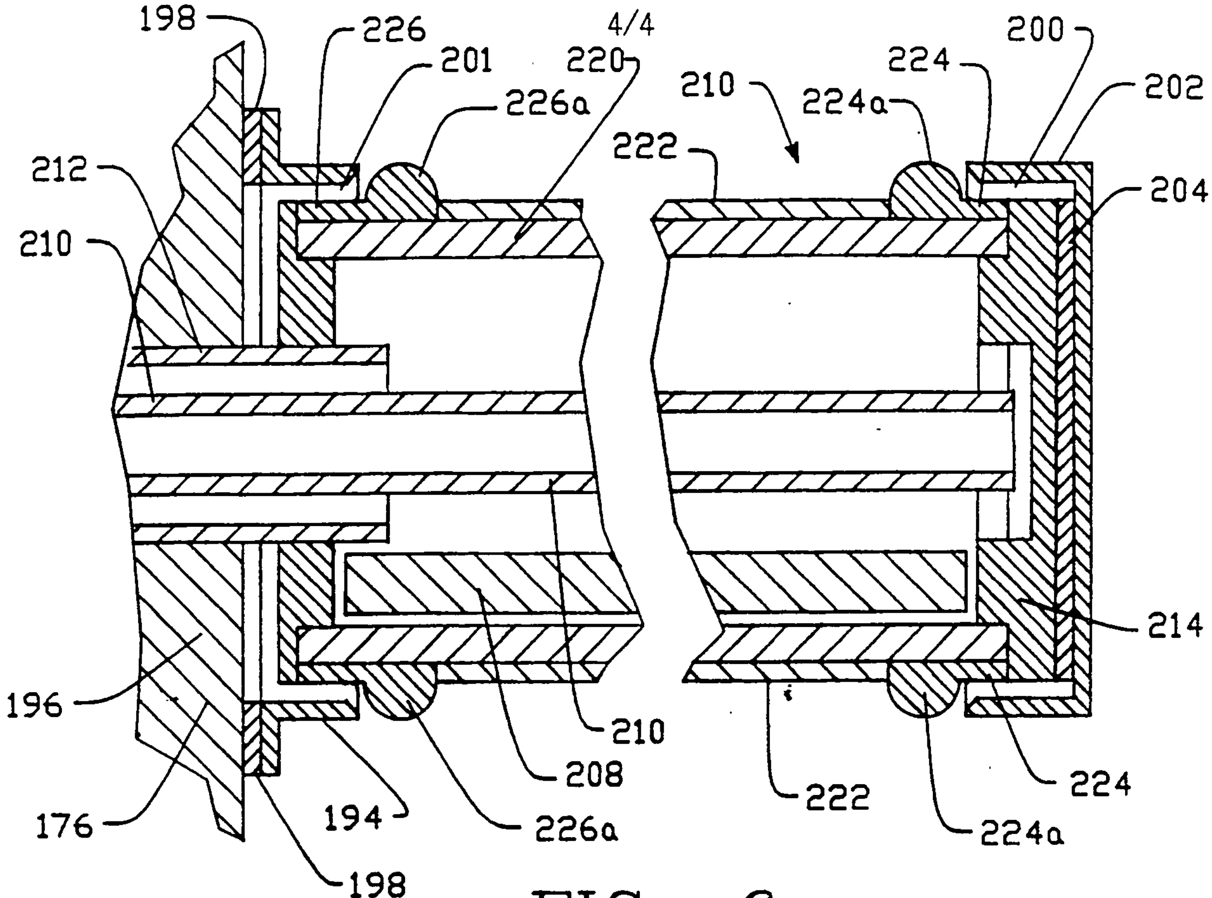
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FIG.—6

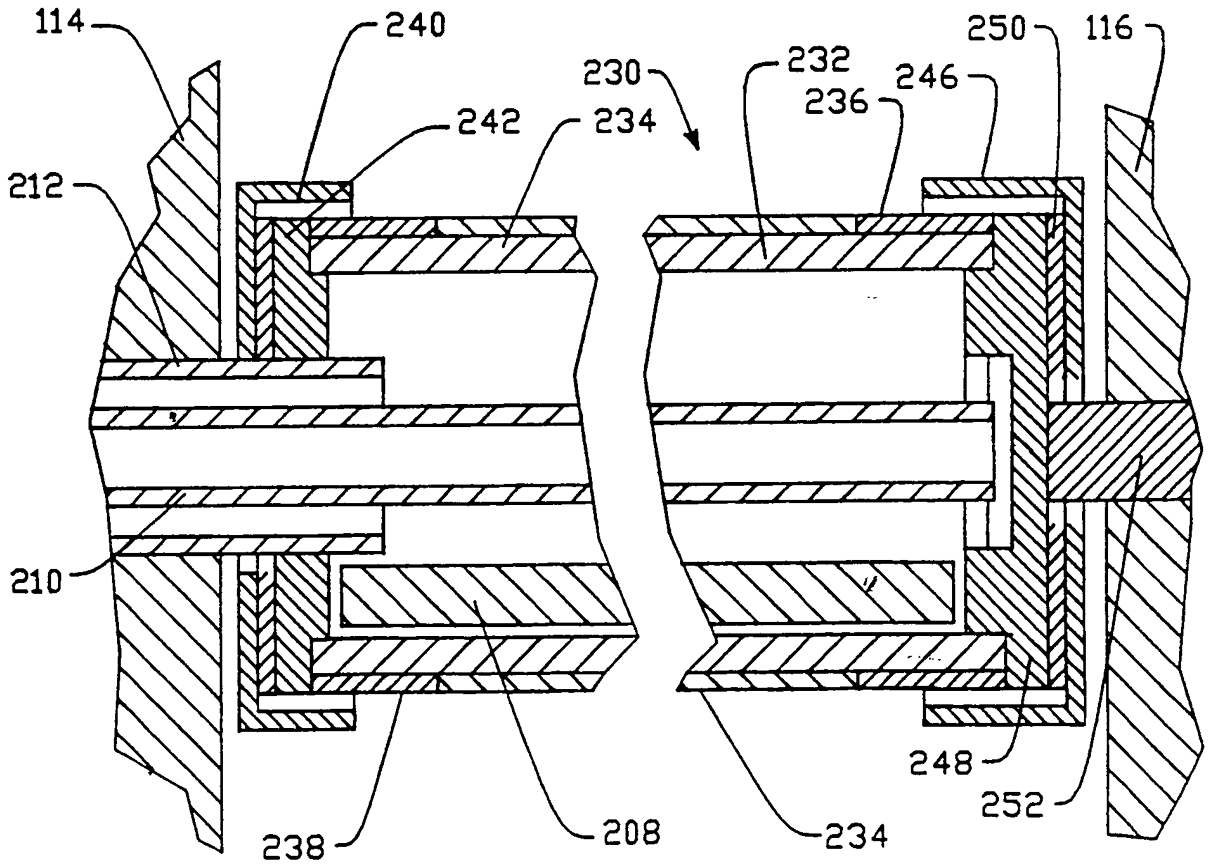
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FIG.—7

INTERNATIONAL SEARCH REPORT

International Application No PCT/US91/05304

I. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): C23C 14/34
US CL : 204/298.21

II. FIELDS SEARCHED

Minimum Documentation Searched

Classification System	Classification Symbols
U.S.	204/298.11, 298.12, 298.16, 298.19, 298.21

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched

III. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
Y	US, A, 4,116,794 (PENFOLD ET AL.) 26 SEPTEMBER 1978 See fig. 8.	1-13
Y	DE, A, 3,229,969 (ERBKAMM) 21 APRIL 1983 See figs. 1-2.	1-13
Y	JP, A, 1-215,975 29 AUGUST 1989, see fig. 1. (PROMETRON TECHNICS)	1-13
Y	US, A, 3,897,325 (AOSHIMA ET AL.) 29 JULY 1975 See fig. 1.	1-13
Y	Hosokawa et al., "Self-sputtering phenomena in high rate coaxial cylindrical magnetron sputtering", J. Vac. Sci. Technol., vol. 14, no. 1, Jan./Feb. 1977, See fig. 2.	1-13
Y	US, A, 4,443,318 (McKelvey) 17 August 1984 See fig. 1.	1-13

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search: 12 NOVEMBER 1991

Date of Mailing of this International Search Report: 25 NOV 1991

International Searching Authority: ISA/US

Signature of Authorized Officer: Ngoc-Ho Nguyen

NGOC-HO

Fr N. NGUYEN

...IONAL DIVISION

International Application PCT/US91/05304

FURTHER INFORMATION C NTINUED FROM THE SECOND SHEET

Y	US, A, 4,519,885 (INNIS) 28 MAY 1985 See fig. 1.	1-13
Y	US, A, 4,445,997 (McKELVEY) 01 MAY 1984 See fig. 1.	1-13
Y	US, A, 4,668,373 (RILLE ET AL.) 26 MAY 1987 See fig. 1.	14-27
Y	US, A, 4,486,289 (PARSON ET AL.) 04 DECEMBER 1984 See fig. 3.	14-27
Y	US, A, 4,485,000 (KAWAGUCHI ET AL.) 27 NOVEMBER 1984 See figs. 1-9.	14-27

V ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers ______, because they relate to subject matter [12] not required to be searched by this Authority, namely:

2. ☐ Claim numbers ______, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

3. ☐ Claim numbers ______, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remarks on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.